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Who Should Conduct Aeronautical R & D For The Federal Government?

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H. HARVEY ALBUM

AUGUST 1977

Jointly sponsored by the
NATIONAL AERONAUTICS AND SPACE AGENCY

SCHOOL OF BUSINESS AND MANAGEMENT

PEPPERDINE UNIVERSITY

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WHO SHOULD CONDUCT AERONAUTICAL R&D FOR THE FEDERAL GOVERNMENT?

by

H. Harvey Album

August 1977

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August, 1977

ABSTRACT

A study was conducted to determine the relative strengths and basic rationale for government use of various institutions to conduct aeronautical research and development (R&D) for the Federal Government. The nation's aeronautical R&D institutions were divided into five categories: manufacturing companies, service R&D companies, non-profit R&D institutions, universities, and government laboratories. The relative roles of these institutions were delineated in regard to conducting basic research, applied research, technology advancement, and development in aeronautics for the Government. The relative strengths and roles of the National Aeronautics and Space Agency (NASA) laboratories were evaluated within the total context of all of the nation's aeronautical R&D institutions.

A total of 25 of the nation's leaders in aeronautical R&D participated in the study. There was an equal number of leaders from each of the five main aeronautical R&D institutions in the United States. The investigation was conducted using both a survey questionnaire and a new conferencing method called the tributary technique. The tributary technique was devised to obtain direct quantitative measurements of subjective judgments by groups that have both common and highly competitive objectives.

The nation's aeronautical R&D institutions have characteristic differences which make them individually suitable for particular types of work. The basic strengths of these institutions produce a pattern of complementary capabilities that properly overlap, but the nation is fortunate in having at least one or two institutions that are particularly well suited for each category of work. For example, it was found that government laboratories, in general, and especially NASA laboratories, should be the prime national producers of applied research in aeronautics. American aeronautics needs the new stimulus of markedly increased outputs of broad-based innovative research from NASA laboratories more than it needs most of the technology advancement and development-oriented programs currently underway in these laboratories. The Government should use manufacturing companies for the vast bulk of development, most technology advancement, and a substantial amount of applied research in aeronautics. However, the Government will have to implement programs to encourage the transfer of full information on technology and research advancements, from the companies that do this work for the Government, to competing companies that also need the results. Universities should be the primary sources of basic research. Service R&D companies and non-profit R&D institutions provide valuable, specialized, supplementary technical capabilities and other unique attributes, which together span the entire spectrum of aeronautical R&D.

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PREFACE

This investigation was made possible through the cooperation of 27 separate organizations in Government and the private sector. The study presents subjective judgments on fundamental rationale as to why the Federal Government should use particular segments of the aeronautical community to conduct basic research, applied research, technology advancement, and development in aeronautics. A total of 25 of the nation's leaders in aeronautical research and development (R&D) participated in the study. The participants are listed in the next section. All participants were directly responsible for work conducted for the Federal Government. Thus, they all had competitive vested interests in the results of this study. Many of them had divergent personal views on the subject as a result of years of experience within different segments of the aeronautical R&D community. Therefore, this investigation had substantial potential for producing conflicting viewpoints among the participants.

Similarly, the reader will undoubtedly have his own initial views on these issues, if he has been concerned with aeronautical R&D. This publication is arranged in a form that will allow the reader to review the processes, determinations, and logic that the participants went through during the course of the investigation. Even the author was surprised at the extent of agreement that emerged within and among the various groups of participants. The data and observations indicated that the participants were profoundly influenced in their thinking as they came to grips with basic issues involved in determining where particular segments of the aeronautical R&D community best fit into the overall structure of work for the Federal Government. Hopefully, the reader will also gain an expanded understanding of the relative strengths and importance of the various segments of the aeronautical R&D community as he reviews judgments presented from different vantage points.

The author takes responsibility for this investigation as it has been influenced by its organization, construction, and other methodology. He is solely responsible for statements made in the introduction, interpretation of the results, side comments, personal observations, conclusions, recommendations, and comparisons with other published data, opinions, and policies. They do not necessarily represent the positions of individual participants, the sponsor, or any of the cooperating organizations.

The author thanks the following members of the School of Business and Management of Pepperdine University who influenced this investigation. Stewart E. Fliege, the principal faculty advisor on the study, provided invaluable guidance on planning, methodology, interpretation, and presentation of the results. The author also acknowledges the contribution of Stephen H. Achtenhagen who periodically reviewed the progress of the investigation, influenced the methodology, and provided many fine ideas on handling the data. Additionally, thanks are due to Wayne L. Strom who, during his teachings on behavioral theory, laid the groundwork from which the author was able to develop the tributary conference technique described in this publication. Kenton L. Anderson, in his teachings, provided substantial insight into the characteristics of organizations, the factors that differentiate them, and the elements of effective organizational structures. Lisa McCormack and various members of the Dean's office of the School of Business and Management provided valuable administrative assistance for this project. Ruth D. Atteberry, Associate Dean, provided excellent editorial review and advice on preparation of this publication.

This investigation partially was sponsored by the National Aeronautics and Space Administration, NASA-Ames Research Center, under Grant NSG-2159 which began on June 1, 1976. The author is indebted to Harry Hornby, Grant Technical Monitor, and J. Lloyd Jones, Chief, Plans and Analysis Office, NASA-Ames Research Center. They were responsible not only for initiating and monitoring this study, but they also provided some excellent ideas and substantial encouragement during the course of the investigation. Finally, thanks are due to Hans Mark, former Director of NASA-Ames Research Center, from whom the author has learned a great deal about R&D organizational management over the past three years.

PARTICIPANTS

The basic results of this study were the product of the individual and combined thinking of 25 of the nation's leaders in aeronautical R&D. Appendix A presents profiles of their backgrounds. Chapter 3 discusses their selection and adequacy of representation (pages 47 to 49). They represented 25 different organizations, large and small, from every sector of the aeronautical R&D community. The participants in this study were as follows:

Manufacturing Companies

Harold D. Altis
Vice President,
Engineering Technology
McDonnell Aircraft Company

William M. Foley
Deputy Director,
United Technologies Research Center
United Technology Corporation

James N. Lew
Senior Vice President,
Engineering
Beech Aircraft Corporation

Robert H. Widmer
Vice President,
Science and Engineering
General Dynamics Corporation

Holden W. Withington
Vice President,
Engineering
Boeing Commercial Airplane Company

Service R&D Companies

John P. Andes
Vice President,
Aerosciences
Calspan Corporation

Coleman D. Donaldson
President
Aeronautical Research Associates
of Princeton

Charles Henderson
Vice President and Director
of Research and Technology
Atlantic Research Corporation

Jack N. Nielsen
President
Nielsen Engineering and
Research, Inc.

Jack Whitfield
Executive Vice President
ARO Inc.

Non-Profit R&D Institutions

Frank E. Goddard
Assistant Director
Research and Advanced Development
Jet Propulsion Laboratory

Ray Laurence Leadabrand
Executive Director
Electronics and Radio Sciences
SRI International

Alan Y. Pope
Associate Director,
Aerodynamics
Sandia Corporation

Elmer H. Schulz
Director
IIT Research Institute

Edward W. Ungar
Associate Director
Battelle Memorial Institute

Universities

Holt Ashley
Professor, Department of
Aeronautical Engineering
Stanford University

Ernest J. Cross
Professor
Aeronautical Engineering
Mississippi State University

Anatol Roshko
Professor
Aeronautics
California Institute of Technology

Martin Summerfield
Professor of
Aeronautical Engineering
Princeton University

Lawrence Talbot
Professor, Department of
Mechanical Engineering
University of California, Berkeley

Government Laboratories

R. Kenneth Lobb
Technical Director
Naval Air Development Center

Oran W. Nicks
Deputy Director
Langley Research Center
National Aeronautics and
Space Administration

Colonel Albert E. Preyss
Commander
A.F. Flight Dynamics Laboratory
U.S. Air Force

Irving C. Statler
Director, Ames Directorate
U.S. Army Air Mobility Research
and Development Laboratory

Robert E. Supp
Deputy Director
A.F. Aero Propulsion Laboratory
U.S. Air Force

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Chapter 1

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents an executive summary, conclusions, and recommendations from the investigation discussed in this publication.

GENERAL

This investigation was conducted to determine what relationships, if any, exist among the relative strengths of the nation's aeronautical research and development (R&D) institutions for conducting basic research, applied research, technology advancement, and development in aeronautics for the Federal Government. A total of 25 of the nation's leaders in aeronautical R&D participated in the study. There was an equal number of leaders from each of the five main aeronautical R&D institutions in the United States: manufacturing companies, service R&D companies, non-profit R&D institutions, universities, and government laboratories. The institutions and areas of work are defined in Appendix B on pages 174 through 176. The investigation was conducted using both a survey questionnaire and a new conferencing method called the tributary technique. The tributary technique was devised to obtain direct quantitative measurements of subjective judgments by groups that have both common and highly competitive objectives. The participants were able to express their judgments in confidence since they could be identified only by institutional affiliation. The participants' points of view were cast in the form of consensuses of judgments for the total group of all participants and for the sub-groups from the various institutions. The results indicated that there was significant agreement among the total group of all participants on 96 percent of their judgments. The level of agreement within any group was taken as being significant only when there was a probability of at least 95 percent that the group consensus judgment was the result of a meaningful group determination rather than chance. The probability of chance for many judgments was less than 1 in 1000.

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The consensus judgments by the sub-groups representing the different aeronautical R&D institutions were often quite different from each other. Natural self-oriented biases frequently influenced the judgments of the sub-groups from the various institutions. However, a careful analysis of all judgments in the study indicates that institutional biases essentially were balanced out by using consensus judgments based on averages of the numerical judgments of all 25 participants. These consensus judgments gave equal weights to viewpoints from the various institutions. The conclusions presented in this section were therefore based upon the consensus of judgments of all the participants as a group.

There are too many conclusions that can be drawn from the wide range of results obtained from this investigation to do justice to them all. The divergent views of the sub-groups and the nature of biases may be very important relative to many issues. It also may be vital to know which rationales were rejected and what the extent of agreement was on these viewpoints. In fact, the reader may often wish to draw his own conclusions from the results relative to specific issues at hand.

However, there are some important general conclusions and recommendations that can be formulated, based on the overall views of the entire group of aeronautical leaders. First, one must accept the premise that this total group of aeronautical leaders was probably as knowledgeable about America's aeronautical R&D institutions as any group that might be convened. It then stands to reason that significant agreement among these aeronautical leaders, as a group, probably yielded correct determinations of the relative strengths, supporting rationale, and best roles for these institutions in regard to conducting aeronautical R&D for the Federal Government.

The following general conclusions are based upon the overall group consensus judgments of the 25 aeronautical leaders and other information gained during this investigation. General conclusions are presented for each of the five aeronautical R&D institutions, in turn, and then for the laboratories of the National Aeronautics and Space Administration (NASA), which are a special case within the general category of government laboratories.

MANUFACTURING COMPANIES

Manufacturing companies are strongly oriented, in all their R&D activities, toward achieving competitive, profitable, manufactured products. Their highly directed attention to end products yields characteristics that coincide, better than those of any other aeronautical R&D institution, with the Government's need for highly effective, concentrated, and well organized efforts in the final stages of the R&D process. At the same time, the product orientation of manufacturing companies greatly reduces their usefulness to the Government for work in the early stages of aeronautical R&D and limits their technical activities in other ways that broadly impact the progress of American aeronautics.

Development. Manufacturing companies are by far the most logical institutions to conduct the vast bulk of development work in aeronautics for the Federal Government. Manufacturing companies have the greatest ability to produce a totally satisfactory product, including post-manufacturing support. The potential for volume production provides manufacturing companies the proper motivation to carry development programs the entire way from inception to successful manufactured products. Manufacturing companies characteristically produce the highest quality of development work. They have the highest ability of any of the aeronautical R&D institutions to focus on achieving solutions to specific real problems. Government funding for development programs in manufacturing companies helps to maintain their world-wide competitive positions. Such funding is essential in order to create new products that are in the national interest, when these development programs are beyond the financial capability of industry.

However, manufacturing companies should not have more than a very small percentage of the total capital value of major aeronautical experimental facilities built by the Government. Manufacturing companies are also not the best sources for impartial technical guidance to the Government on development contracts to other organizations.

Technology advancement. Manufacturing companies should play the dominant role in aeronautical technology advancement for the Federal Government. They have the facilities (manufacturing) and the knowledge (technology) to do it. Manufacturing companies characteristically produce the highest quality of technology advancements and they have the greatest ability to focus their efforts on achieving important gains. The Government should fund technology advancement work in manufacturing companies so that they can stay abreast of new advancements and gain a world-wide competitive advantage. Furthermore, technology advancement is part of the logical process of developing needed high technology products. It is also important for manufacturing companies to conduct technology advancement for the Government in order to define cost performance, risks, and profit potential of possible new products.

In other words, foot the bill. Won't manufacturing companies keep abreast of developments without government money?

However, there is a serious drawback in placing the vast bulk of the Government's contracts for technology advancement with manufacturing companies. Manufacturing companies are characteristically the least willing of any aeronautical R&D institution to provide outside organizations with full information on the results of these programs. Nevertheless, the need to use manufacturing companies to advance aeronautics technology is too compelling to direct most of this work into more open aeronautical R&D institutions. This dilemma cannot be reconciled unless the Government's intervention in the normal process of industry competition, by funding technology advancement in certain firms, is also accompanied by effective governmental measures to help all aeronautical firms share fully in the results.

Manufacturing companies have next-to-the-lowest ability of all five aeronautical R&D institutions to provide the Government with impartial technical guidance on technology advancement contracts with other organizations. The Government needs other institutions for this function.

Applied research. Manufacturing companies should play the second-greatest national role, among the five institutions, in providing applied research in aeronautics for the Government. Applied research is part of the logical process of developing needed high technology products in manufacturing companies. Applied research will help manufacturing companies stay ahead in development and gain a national competitive advantage. Manufacturing companies sometimes have unique capabilities to carry out applied research by virtue of their proximity to development problems. When applied research is conducted in manufacturing companies it helps them attract, develop, and retain people with needed skills.

There are some significant factors that should moderate the extent of the role played by manufacturing companies in conducting applied research for the Federal Government. Manufacturing companies characteristically produce nearly-the-lowest quality of applied research among the five aeronautical R&D institutions. Manufacturing companies are the least willing of all aeronautical R&D institutions to provide full information on the results of their government-funded research. While applied research in manufacturing companies helps them guide their own organizations' work, it does not help the Government guide its contract work with other organizations. Manufacturing companies are the least able of any institution to provide the Government with impartial technical guidance on applied research contracts with other organizations. In addition, research groups in manufacturing companies will not have constant access to major government-built aeronautical experimental facilities, which might be advantageous to research. Only a small percentage of these facilities should be located at or under the control of manufacturing companies.

Basic research. Manufacturing companies should play the smallest role of any aeronautical R&D institution in government-sponsored basic research. However, they should do some basic research. Sometimes a manufacturing company has a unique capability to conduct basic research of a particular type. Basic research provides manufacturing companies with information on new advancements. Working in the field helps manufacturing companies capitalize on these new findings by others and it allows them to move these advancements into the applied research phase. The work in basic research gives manufacturing companies a far-term perspective. It helps them avoid near-term focusing of their R&D efforts and thus prevents technological surprise.

However, manufacturing companies characteristically produce the lowest quality of basic research of the five institutions. They are the least willing to provide full information on their results. Manufacturing companies should not have more than a small percentage of the major, government-built, experimental facilities that might also be useful in basic research. While basic research will help manufacturing companies in guiding their other work, it will not materially aid the Government in obtaining technical guidance for its other basic research contracts. Compared to other aeronautical R&D institutions, manufacturing companies are characteristically the worst sources of impartial technical guidance to the Government on basic research contracts with other organizations.

SERVICE R&D COMPANIES

Service R&D companies tend to be highly effective technical organizations in certain specialty areas. They are oriented to providing services that augment permanent staffs in government laboratories, industry, and non-profit R&D institutions. The Government can draw on the available pools of specialized talent in service R&D companies without creating as permanent an investment in personnel as would be required by conducting such work in government laboratories. While the specialized roles of service R&D companies should span the entire spectrum of aeronautical R&D, their greatest natural roles relative to other institutions tend to be in technology advancement and applied research. Service R&D companies have a characteristic capability to focus on achieving solutions to specific real problems that is second only to that of manufacturing companies. Service R&D companies tend to be more willing to supply full information on the results of government-funded work than manufacturing companies, but service R&D companies are not so open in this respect as are the other aeronautical R&D institutions. Service R&D companies should have a minor proportion of the nation's major aeronautical experimental facilities built by the Federal Government.

Development. Service R&D companies should play a small role in conducting aeronautical development work for the Government. The activities of service R&D companies in conducting development should be far below that of manufacturing companies, but roughly on a par with government laboratories. Service R&D companies may achieve the most-effective product development in technical areas where they have unique capabilities. This may well be the case for certain relatively small aeronautical products. Service R&D companies may provide an economical source of development. In general, the quality of development work in service R&D companies is second only to that of manufacturing companies. Service R&D companies characteristically have at least as good an ability to provide impartial technical guidance to the Government on development contracts as other institutions in the private sector.

Technology advancement. Service R&D companies should play a small but significant overall role in technology advancement for the Government. Their role in advancing aeronautical technology should be second only to that of manufacturing companies, but about equal to the role of government laboratories. Service R&D companies have special capabilities and economically can supply technology advancements in a timely fashion. Service R&D companies are able to tie technology to a product or other end application. In general, the quality of work in technology advancement produced by service R&D companies is second only to that of manufacturing companies. However, service R&D companies are not the best sources for impartial technical guidance to the Government on technology advancement contracts with other organizations.

Applied research. Service R&D companies should play a small but significant national role in conducting applied research in aeronautics for the Federal Government. Service R&D companies supply applied research economically and in a timely fashion. The quality of their applied research is characteristically about average among the five aeronautical R&D institutions. However, service R&D companies rank next to last in their ability to provide the Government with impartial technical guidance on applied research contracts with other organizations.

Basic research. Service R&D companies should probably play only a very minor role in basic research. The extent of their activities in basic research should be next to the lowest among all aeronautical R&D institutions. The quality of basic research in service R&D companies tends to be lower than that of all the aeronautical R&D institutions, except manufacturing companies. The ability of service R&D companies to provide the Government with impartial technical guidance on basic research similarly tends to be next to the lowest of the five aeronautical R&D institutions.

NON-PROFIT R&D INSTITUTIONS

Non-profit R&D institutions are similar to service R&D companies in that they supply valuable supplementary capabilities in aeronautical R&D for the Government. Non-profit R&D institutions sometimes have unique technical capabilities in special fields. The role of non-profit R&D institutions in performing aeronautical R&D spans the entire spectrum of R&D. However, as producers of aeronautical R&D, non-profit R&D institutions play their greatest roles in basic and applied research. Non-profit R&D institutions should have a small percentage of the major aeronautical experimental facilities built by the Government.

The organizational features of non-profit R&D institutions also make them uniquely useful to the Government for certain other aeronautical R&D tasks. They can be used by the Government for objective technical analyses, technical support, and for second sources on technical evaluations. Non-profit R&D institutions do not compete with industry by manufacturing products nor do they have stockholders demanding profits, dividends, and capital gains. Non-profit R&D institutions can thus work with industry and can protect proprietary information in a fashion similar to government organizations. At the same time, non-profit R&D institutions are in the private sector and they are not subject to many of the constraints placed on government organizations. Thus, government organizations can use non-profit R&D institutions to add technical competence and flexibility to their capability to accomplish the Government's portion of the technical work. Non-profit R&D institutions tend to have a greater ability to focus on solving specific real problems than do government laboratories. Non-profit R&D institutions are exceeded in this respect only by manufacturing companies and service R&D companies. However, non-profit R&D institutions are more willing to provide outside organizations full information on the results of their work for the Government than are manufacturing companies or service R&D companies.

Development. Non-profit R&D institutions should conduct only a very small amount of the total development work in aeronautics for the Government. In fact, non-profit R&D institutions should be the smallest participant in aeronautical development of any R&D institution, except universities. Non-profit R&D institutions may have certain unique capabilities in specialized areas which can be of value in performing aeronautical development work. However, the quality of the aeronautical development work by non-profit R&D institutions tends to be next to the lowest among the five aeronautical R&D institutions. On the other hand, the ability of non-profit R&D institutions to provide the Government with impartial technical guidance on development contracts is characteristically at least as good as any other R&D institution in the private sector can provide.

Technology advancement. The relative role of non-profit R&D institutions in aeronautical technology advancement for the Government should be small, but greater than their role in development. Non-profit R&D institutions should play next-to-the-smallest role in performing technology advancement activities in aeronautics for the Government. The Government can use non-profit R&D institutions on the government side of its aeronautical R&D activities and yet circumvent federal restraints. Sometimes there are special government problems or needs where it is necessary to have a non-profit R&D institution conduct technology advancement in order to utilize their non-product objectivity, that is, a lack of commercial bias and absence of coupling to manufacturing. The ability of non-profit R&D institutions to provide the Government technical guidance on technology advancement contracts in aeronautics is second only to that of government laboratories. Non-profit R&D institutions provide a less permanent commitment to personnel than government laboratories. The characteristic quality of technology advancement by non-profit R&D institutions is average among the five aeronautical R&D institutions and it is roughly on a par with the quality of technology advancement work by government laboratories.

Applied research. Non-profit R&D institutions should share significantly in conducting applied research in aeronautics for the Federal Government. The total extent of their applied research activities should add up to substantially less than that of government laboratories and manufacturing companies, but it should be about equal to the roles played by universities and service R&D companies. Non-profit R&D institutions have special organizational characteristics of use to the Government, as mentioned in the previous section. Non-profit R&D institutions bridge the gap between universities and government organizations. The quality of aeronautical applied research from non-profit R&D institutions tends to be second only to that of government laboratories. Non-profit R&D institutions should be used by the Government for applied research if they have the physical resources to do the work required. Their ability to provide the Government with impartial technical guidance on applied research contracts is second only to the ability of government laboratories.

Basic research. Non-profit R&D institutions should play a relatively small, but significant, role in aeronautical basic research for the Government. The total extent of their activities in basic research should amount to substantially less than those of universities and government laboratories. However, non-profit R&D institutions should probably play a larger role in basic research for the Government than service R&D companies or manufacturing companies. The quality of basic research in non-profit R&D institutions is characteristically second only to that of universities. The organizational form of non-profit R&D institutions allows them to work for the Government in a fashion similar to government laboratories and yet circumvent federal constraints. They can function as captive laboratories to the Government and perform basic research on a long-term basis. Non-profit R&D institutions should be used for basic research if they have the necessary talent and the physical resources. However, non-profit R&D

institutions have only an average ability, relative to the other institutions, to provide the Government with impartial technical advice on basic research contracts with other organizations.

UNIVERSITIES

The very characteristics of universities make them ideally suited to be the leading institution for conducting basic research in aeronautics for the Federal Government. Their orientation towards education, which is the primary purpose of their institution, creates a climate for concentrating on the fundamentals of aeronautics. Their occupation with students, inquiry, and dealing with basics completely pervades the institution's activities. The general orientation of universities attracts people suited to learning and teaching by virtue of intelligence and independent nature. Universities are naturally the most willing, of all aeronautical R&D institutions, to provide full information on the results of their work for the Government. There is a strong element of striving for objective inquiry that has also been deemed useful in providing technical advice to the Government.

However, the same strong orientations that are so valuable for basic research in universities make them considerably less useful for more applied tasks. Universities tend to have the lowest ability to focus on achieving solutions to specific real problems relative to other aeronautical R&D institutions. Thus, universities are primarily research institutions, with the greatest emphasis on basic research. Universities should have a small percentage of the major aeronautical experimental facilities built by the Government.

<u>Development</u>. The universities have essentially no role in aeronautical development for the Government. No significant rationale has been found to support university activity in development for the Government. Universities characteristically produce aeronautical development work of lower quality than that of any other aeronautical R&D institution. Universities have the lowest ability to provide technical guidance to the Government on aeronautical development contracts. In spite of their probable impartiality, it does not seem wise to use

disproportionately large numbers of university professors on government advisory groups for aeronautical development programs.

Technology advancement. Universities should play only a minute role in aeronautical technology advancement for the Government. The universities' activities in technology advancement should be substantially less than the roles played by all other aeronautical R&D institutions. However, there are some instances where universities can provide unique sources for technology advancement. A small amount of work in this area can sometimes further the training of students for the later practice of engineering. It would also help universities in interfacing better with industry. The presence in universities of fundamental scientists contributes to the innovative thinking process essential to the achievement of large technology jumps. On the other hand, universities characteristically produce the lowest quality of work in technology advancement of any aeronautical R&D institution. They have the lowest ability to provide the Government with technical guidance on technology advancement contracts with other organizations, even though university advisors are likely to be impartial. As in the case of development, it does not seem appropriate to use disproportionately large numbers of university professors on senior government advisory groups that influence critical decisions on technology advancement programs in aeronautics.

Applied research. Universities should have a substantially lesser role in conducting applied research in aeronautics for the Government than the roles of either government laboratories or manufacturing companies. However, the extent of university activities in applied research should be roughly on a par with service R&D companies and non-profit R&D institutions. Applied research is an integral part of the educational process in engineering schools. Graduate engineering students, who are low cost, energetic, and questioning, are often strongly motivated towards applied research. Universities sometimes have the unique facilities and the talent to do applied research. The long lifetimes typical of some applied research projects are compatible with university patterns. On the other hand, the quality of university-applied research in aeronautics is characteristically below that of almost any other aeronautical R&D institution. Universities are about average, among the R&D institutions, in their ability to provide the Government impartial technical guidance on applied research contracts with other organizations.

Basic research. Universities should perform the major national role in providing aeronautical basic research for the Government. In fact, the role of universities in providing aeronautical basic research for the Government should be roughly equivalent to the combined roles of all other aeronautical R&D institutions. Universities have atmospheres that draw people qualified by independence and motivation to do basic research. Graduate students, who are low cost, energetic, and questioning, have an idealistic approach to basic research. Universities characteristically perform the highest quality of basic research of any aeronautical R&D institution. Basic research is an integral part of the education process. Universities should be funded by the Government to do basic research to further the development of specific capabilities that are in the national interests. Universities are probably second only to government laboratories in ability to provide the Government with impartial technical guidance on basic research contracts.

GOVERNMENT LABORATORIES

The government laboratories provide important technical contributions to aeronautical R&D and play vital central management roles within the total complex of America's aeronautical R&D institutions. Government laboratories gain their natural orientations and their most important capabilities from three main factors: (a) their positions within the Government, (b) the knowledge they derive from the technical work they perform, and (c) the substantial resources they can direct toward technical objectives. The most important role of government laboratories is in technical guidance within the Government for planning and executing aeronautical R&D programs. Government laboratories characteristically have the greatest ability, of any aeronautical R&D institution, to provide impartial technical guidance to the Government on contracts from basic research through development.

Government laboratories are vital to communications and working relationships between the Government and the nation's other aeronautical R&D institutions. Government laboratories should be advocates, critics, and interpreters within the Government, of advancements that have been or could be made by all of the nation's aeronautical R&D institutions. Government laboratories should play a major role in translating the nation's aeronautical needs into specific research and technology advancement tasks. They have the resources to move fundamental advancements into the more applied stages of the R&D process. Government laboratories should strive to increase the overall national capability in aeronautical R&D. Government laboratories should not only produce technical advancements, in-house and under contract, but they should also use all their influence and resources to insure that the results of R&D purchased with tax dollars are made widely available to all American aeronautical R&D institutions. Government laboratories are second only to universities in their willingness to provide outside organizations with full information on government-funded research and technology.

Government laboratories should conduct some in-house technical work in all phases of aeronautical R&D in order to provide skills, knowledge, and understanding so that they can properly perform their other broad government roles in aeronautical R&D. They have the most diversified natural capabilities of any aeronautical R&D institution, as reflected by their being the only institution which produces a quality of work that characteristically ranks in the upper half of institutions over the entire aeronautical R&D spectrum. However, government laboratories are best suited and are most needed as major producers of basic and applied research in aeronautics. The position of government laboratories within the Government also leads to a lack of orientation and creates physical restrictions that prevent them from being top performers in technology advancement and development work. Government laboratories characteristically have next-to-the-lowest ability to focus on achieving solutions to specific real problems compared to the other aeronautical R&D institutions. Government laboratories should be the guardians of most of these government facilities so that the results from these facilities and access to them will be available to all segments of the aeronautical R&D community.

The role of government laboratories as a primary producer of research is greatly enhanced by their access to major aeronautical experimental facilities built by the Government. However, a large portion of major government experimental facilities should also be made easily available to other aeronautical R&D institutions by placing them in central government test centers which do not have their own resident government R&D groups.

Development. Government laboratories should play only a very small role in conducting their own development work. They should do development work in areas where they already have a unique capability for it. Development work by government laboratories provides an arsenal system of manufacturing in areas where there is little industrial/commercial interest. Government laboratories must be engaged in development to provide knowledge and life cycle laboratory support for operational systems. However, government laboratories characteristically produce about average quality of development work relative to the other four aeronautical R&D institutions. Thus, government laboratories should not be major development organizations.

Technology advancement. Government laboratories should play a small but significant role in providing aeronautical technology advancements. Their in-house efforts in technology advancement should be far below that of manufacturing companies. Government laboratories and service R&D companies should be the two greatest sources of technology advancements in aeronautics. Technology advancement should be done within government laboratories in order to provide knowledgeable buyers of the developed product. Technology funded within government laboratories often provides unique facilities accessible to development groups in the public and private sectors. Government laboratories have resources to support prototype development, which are not available to a single industrial organization. Technology that is funded within the Government becomes available to all aeronautical R&D institutions, which helps to maintain an open competitive environment for the developed product. However, government laboratories characteristically produce only average quality of work in technology advancement relative to the other four aeronautical R&D institutions.

Applied research. Government laboratories should be the greatest source of applied research in aeronautics for the Government. Government laboratories characteristically produce the highest quality of applied research of any aeronautical R&D institution. Government laboratories should conduct applied research to provide knowledgeable leadership for coordinating and guiding aeronautical R&D. Applied research should be done by government laboratories to provide quick response capabilities to solve the Government's operational systems problems. Large-scale facilities which might be required for applied research can be best built and operated by the government laboratories. Government laboratories should conduct applied research when there is a lack of commercial incentives. The applied research done by government laboratories provides them information, skill, and knowledge necessary to permit them to conduct independent evaluations of competitive R&D.

Basic research. The government laboratories should be second only to universities, among all aeronautical R&D institutions, as the nation's primary source of government-funded basic research in aeronautics. Basic research conducted within government laboratories facilitates a transfer of basic research knowledge into applied research. Basic research in government laboratories provides a reservoir of aeronautical knowledge in the public domain. Government laboratories should particularly conduct basic research in cases where the research can benefit from any unique facilities they may have. Government laboratories could provide a stable environment for long-term, high-risk research.

NASA LABORATORIES

The current conclusions regarding the relative strengths and roles of NASA laboratories are based on consideration of the roles played by all aeronautical R&D institutions. The laboratories in NASA fall within the general class of government laboratories. However, there are substantial differences between NASA laboratories and other government aeronautical laboratories. Three government agencies have their own laboratories engaged in aeronautical R&D: the Department of Defense (Army, Navy, and Air Force), the Department of Transportation, and the National Aeronautics and Space Administration. At present, NASA is the only one of these three agencies that is not itself a prime customer for the final products resulting from its in-house and contracted aeronautical R&D. NASA is the only agency that does not conduct regular aeronautical operations using these products. NASA is not a major developer nor a purchaser of civil aircraft. These activities are the respective domains of aircraft manufacturing companies and commercial airlines. Furthermore, the National Aeronautics and Space Act of 1958 does not give NASA the roles of coordinating national aeronautical R&D nor providing advisory services to other aeronautical institutions as was legally required of its predecessor, the National Advisory Committee for Aeronautics (NACA). The NASA is an independent government agency charged with promoting advances in aeronautics for other agencies and institutions. Therefore, the general conclusions of this study for government laboratories must be made more specific for NASA laboratories.

The laboratories in NASA should be prime producers of basic and applied research in aeronautics. American aeronautics needs the new stimulus of massive outputs of broad-based innovative research from NASA laboratories more than it needs most of the specialized technology advancement and development-oriented programs currently underway in NASA laboratories. NASA laboratories are in excellent central positions to conduct research by virtue of their locations in a separate government agency. NASA laboratories have a natural orientation for broad-based, systematic, and highly innovative research. The research in NASA laboratories will aid NASA in guiding its own aeronautical R&D contract programs. It will also assist them in certain high-level government advisory functions and in long-term studies of the national benefits to be gained from aeronautical R&D.

The rationale that indicates that government laboratories, in general, should be prime producers of aeronautical basic and applied research largely holds true for the specific case of NASA laboratories. In fact, much of this rationale stemmed from consideration of NASA laboratories. The NASA laboratories have many of the same characteristics attributed to the government laboratories, such as their exceptionally great willingness to provide full information on the results of government-sponsored R&D. The NASA laboratories should share in the role of other government laboratories as users and guardians of a major portion of the nation's large-scale aeronautical experimental facilities built by the Government. These major NASA experimental facilities make it possible for NASA laboratories, in particular, to be mass producers of high-quality innovative research.

Development. Perhaps a quarter of the current work by NASA laboratories in aeronautics is so highly oriented toward specific applications and hardware that it must be considered in the development phase of aeronautical R&D. NASA laboratories should be hardly involved in in-house development activities in aeronautics. There is no valid rationale for NASA laboratories to conduct their own aeronautical development activities. The quality of development work by NASA laboratories is below that of manufacturing companies and service R&D companies; however, the quality of aeronautical development work by NASA laboratories is better than that of the old NACA and about equal to that of other government laboratories. The characteristic quality of development work by government laboratories is only average relative to the other four aeronautical R&D institutions. However, there are additionale rationales for other government laboratories to conduct development work in aeronautics. Hence, the development-oriented work in NASA laboratories should not constitute nearly so large a portion of their total aeronautical activities as is apparently the case.

Technology advancement. NASA laboratories currently seem to be devoting about a third of their efforts in aeronautics to technology advancement. The role of NASA laboratories in technology advancement should be far smaller than it is at the present time. The only valid rationale for NASA laboratories to conduct technology advancement is if they have an existing unique capability to accomplish it. The quality of technology advancement from NASA laboratories is about the same as it was for the NACA laboratories. However, NASA laboratories should probably devote even less work to technology advancement than did NACA, unless NASA assumes similar roles. The NASA laboratories characteristically produce about the same quality of technology advancement as do government laboratories in general, which is about average among the five aeronautical R&D institutions. The small role of government laboratories in technology advancement is justified by additional rationale beyond that which applies to NASA laboratories. It therefore seems logical that NASA laboratories should have an even smaller role in conducting aeronautical technology advancement than do other government laboratories.

Applied research. The primary role of NASA's aeronautical laboratories should be to conduct applied research. The nation's aeronautics industry and other governmental agencies need more applied research from NASA laboratories than the combination of their output in all other categories of NASA's in-house aeronautical R&D. The output of applied research from NASA laboratories should be roughly doubled. Such an increase is necessary in order to bring the supply of NASA's applied research into better balance with the relative demand. Apparently, NASA's aeronautical laboratories are devoting a far smaller portion of their total in-house aeronautics efforts to applied research than did the old NACA laboratories. Even the quality of aeronautical applied research by NASA's laboratories is lower than that of NACA laboratories.

There is substantial rationale for NASA laboratories to assume a prime national role in providing massive amounts of stimulative, systematic, and innovative applied research to the aeronautics industry. The NASA laboratories should conduct applied research in order to permit independent evaluation of competitive aeronautical R&D. In-house applied research by NASA provides it the knowledge necessary to contract aeronautical R&D properly to the private sector. The applied research in NASA laboratories provides NASA the knowledge necessary to give leadership for coordinating and guiding R&D. The large-scale facilities available in NASA can benefit applied research. The NASA should conduct applied research where there is a lack of commercial incentive. The quality of applied research from NASA laboratories is characteristically about equal to that of all government laboratories in general, which tend to produce higher quality of applied research than any other aeronautical R&D institution.

Basic research. The second greatest role for NASA laboratories in aeronautics should be in basic research. The basic research output of NASA laboratories should be almost doubled in order for NASA to play its proper national role in this area. The percentage of basic research produced by NASA's aeronautical laboratories today seems to be roughly half as large as it was for the old NACA laboratories. The quality of NASA's basic research in aeronautics also seems to be lower than it was under NACA laboratories.

There are a number of reasons why NASA should conduct basic research. Basic research by NASA provides a reservoir of aeronautical knowledge in the public domain. The NASA laboratories should conduct basic research in areas where they have the talent. The quality of basic research in NASA aeronautical laboratories is about equal to that of overall government laboratories, which ranks second only to that of universities. The NASA laboratories should do basic research in areas where they have unique facilities. Most of the major government-built experimental facilities should remain within government laboratories, including within NASA laboratories. The NASA experimental facilities would be available to NASA resident research groups. Basic research in NASA laboratories facilitates transfer of basic research knowledge into applied research.

SPECIAL RECOMMENDATIONS

The following personal recommendations also are made based on an analysis of all the information gained during the course of this investigation.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The NASA should consider advocating that it become the central aeronautical research agency for the Federal Government. This role for NASA should not exclude highly mission-oriented research efforts by other government laboratories. However, NASA could provide an efficient central agency for the bulk of the Government's stimulative aeronautical research efforts for both military and civil aeronautics.

Serious consideration should be given in NASA to advocating that it also assume a role as a national advisory and coordinating body for aeronautical R&D. The rationale for NASA's activities in aeronautics, as a government laboratory system, would become far stronger if such working links to outside technology programs, development programs, and aviation operations were established.

The NASA should consider setting up a special internal management structure for aeronautics similar to that of the old NACA. This should be a partnership arrangement with "interlocking boards of directors" such as NACA had for over 40 years. It probably will not be possible for NASA to serve effectively as the central government coordinating, advisory, and research agency in aeronautics unless it establishes such a management link with the nation's prime aeronautical organizations.

An investigation should be conducted to examine the role of NASA's contract program in advancing aeronautical R&D. This role might possibly be different than the role of NASA's in-house work in aeronautics which was examined during this investigation.

GOVERNMENT LABORATORIES

Government laboratories should go to extremes to select work that will yield results of maximum value to national aeronautics, as a whole. A careful examination should be made of how government laboratories might improve the transfer of full information, on advances made under government R&D contracts, to all American aeronautical R&D organizations that need it. The government laboratories have substantial influence in industry and they also have the resources to gather information and make it available in a highly usable form.

ALL AERONAUTICAL R&D INSTITUTIONS

Every organization in aeronautical R&D should make a fundamental evaluation of its own strengths, weaknesses, natural orientations, goals, and relationships to other organizations. Numerous case histories and general studies have shown that poor performance by an organization is usually caused by unawareness, neglect, or disregard of these basic factors. The data obtained in the current study suggest that these fundamental considerations, which seem so very simple on the surface, are probably not well understood by many aeronautical R&D organizations.

The tributary technique can be used for many types of fundamental organizational assessments. It is rapid and it reduces the expenditure of top management's time. However, this new technique must be tailored for each situation. The tributary technique requires substantially more preparation and later analysis than do more casual conferencing methods. The timing must be precise and every structural detail has to be carefully worked out in advance. The key to success in using the tributary technique is to pretest every aspect of the final procedure. The tributary technique might be constructed to examine, successively, such things as an organization's strengths, weaknesses, propensities of its people, customer needs, future opportunities, goals, and related management factors.

Advisory group methods for aeronautical R&D can and should be improved. For example, all advisory groups should use segment analysis techniques. Conference structure methods should also be upgraded to fit specific needs. Experience from the current investigation indicates that it is possible to create conference environments, even in highly competitive situations, where advisors can be themselves, represent their own interests, and freely provide their best judgments.

Chapter 2

INTRODUCTION

This investigation examines basic rationale for government use of different institutions to conduct aeronautical research and development. The Government consistently has supported research and development (R&D) in the United States for 150 years. Nevertheless, the history of government involvement in R&D has been rich in controversy (1). The difficulty that the American government has had in formulating policy on R&D, in this basically free enterprise system, has probably never been more evident than over the last decade. The issues historically have fallen into three broad categories: the extent of government financing for R&D, the areas of government support, and the relative roles of government and private R&D institutions. This introduction reviews current problems in all three of these categories in order to establish a complete framework for considering the institutional questions in aeronautical R&D.

FEDERAL SUPPORT FOR R&D

There was a total of about $38 billion invested in R&D in the United States in 1976 (2:2). For over a quarter of a century, the Federal Government has been the source of more than half the funds annually invested in R&D in the United States (3:13; 4:2).[1] However, the federal budgets for R&D have shown a downward trend over the last ten years. Federal funding for R&D steadily increased, in constant dollars, at average annual compound rates between 5.3 and 14 percent from 1953 to 1967 (4:2). The private sector increased its investment in R&D at a compound rate of 7.2 to 7.8 percent during the same period.

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[1]Notation (3:13; 4:2) means Reference 3: page 13 and Reference 4: page 2.

The total national investment in R&D peaked in 1964 at about 3 percent of the gross national product (4:3). At that time, the Federal Government provided roughly two-thirds of all funding for R&D. Federal R&D funding, in constant dollars, reached its maximum in 1967. The federal contribution to R&D dropped from 2 percent to 1.[illegible] percent of the gross national product between 1964 and 1976 (4:3). The private sector continued to support R&D at between 1 and 1.1 percent of the gross national product throughout the years from 1955 to 1976 (4:3; 5:3). Hence, the gradual federal withdrawal from investments in R&D over the last decade was totally responsible for a decline of 27 percent in the annual national investment in R&D to 2.2 percent of the gross national product by 1976 (4:2).

In spite of what seems to be true from the history of civilizations, both ancient and modern, economists have not been able to relate quantitatively investments in national R&D and technological innovation to economic growth. A National Science Foundation report in 1974 pointed out that

> The impact of technological innovation on productivity and economic growth is . . . understood only in general terms. Present knowledge of the causal connection between innovation and economic returns is not sufficient for developing quantitative indicators of the relationship (6:94).

However, there have been studies on return on investment from R&D for companies in specific industries (6:110; 7:25-26; 8) and on the influence of R&D on national economic progress (8:2). The results of these studies have led most economists to recognize that the impact of R&D on economic growth is quite high (8; 9).

The value of federal expenditures for R&D are particularly difficult to quantify in economic terms. Most federal R&D outlays go for defense, space, regulatory activities, and other objectives where the primary benefits to society are not reflected in economic quantities. Two-thirds of the federal expenditures for R&D in 1976 were for defense and space (4:2-3). Other federal R&D programs promote safety, health, the quality of life, intellectual growth, and the general welfare of the nation. The secondary benefits from technical advances from federal R&D programs often impact the national economy. However, the effects are so pervasive that they are difficult to trace and evaluate. The net effects of most federal R&D on the overall national economy is not measurable solely from increased sales and profits for the companies conducting the R&D for the Government. This fact has apparently led some researchers to assume that effects they cannot now directly measure and correlate in economic quantities are not significant. These wild assumptions lead to partial economic analyses which imply that federal R&D does not warrant the investment (10; 11; 12). If such fields as science, medicine, politics, philosophy, and the arts had waited for economic analysis to prove the worth of every effort before attempting to move forward, civilization would probably still be in the Dark Ages.

It is becoming increasingly apparent to wide elements of both the public and private sectors that serious alterations have been occurring in the relative rate of technological progress and the growth of the U.S. economy since the decline of the federal investment in R&D (3; 8; 9; 13; 14; 15; 16; 17). America's per capita income has moved from first to fifth place in rankings relative to other major nations (16:51). The gain in U.S. productivity between 1960 and 1974 was less than that of four other major industrial nations (6:23-24). In fact, America achieved only one-fifth of the increase in productivity that Japan recorded. The patent balance of the United States relative to other nations fell 30 percent between 1966 and 1973 (6:17). The patent balance is the difference between U.S. patents granted in foreign countries and foreign patents granted in the United States. There is little doubt that America's technological and industrial lead has been slipping.

Foreign competition to U.S. manufactured goods, particularly high technology products, has been gaining ground in the world marketplace (8:1; 17:28). While the United States was cutting back on R&D, three other major industrial nations were rapidly and continuously increasing the total percentage of their gross national products that they were plowing back into R&D for future growth (6:4). West Germany and the Soviet Union both had surpassed the United States in the amount they were investing in R&D relative to their total gross national products three years ago. These foreign nations, respectively, spent 2.4 and 3.1 percent of their gross national products for R&D compared to the 2.3 percent expenditure in the United States. Japan spent about 1.9 percent of its gross national product for R&D in 1974. However, if the previous five-year trend of Japan's increases in investments in R&D has continued, then Japan probably surpassed the United States in 1976 (6:4). Thus, the United States will have to increase its relative investment in R&D in order to maintain its competitive position in foreign trade.

There is another possible reason why America's technical innovations have been slowing down. There are indications that both the Government and private industry have been concentrating R&D on near-term problems and achieving evolutionary advances, rather than attempting to risk more time and effort to create major new innovations (17). In fact, the average time from completion of an average research project to final application dropped from about six years over 1960-1970 to only three years between 1970 and 1973 (6:79). Great innovations tend to take more time to adapt for applications and to gain acceptance than do evolutionary advances. Hence, recent trends towards "relevance" and requirements for complete financial proofs of the value of highly advanced long-term research may well be stifling America's continued progress.

There has been considerable discussion regarding whether the Federal Government should increase funding for basic research, applied research, or development. Many authors argue that the appropriate place for the Federal Government to provide support for the commercial sector would be in basic and applied research, rather than for development (for example, 8:38; 18; 19; 20:59). It is argued that there is a tendency for commercial firms to invest most heavily in the later stages of the R&D process where they can gain competitive advantages. Industry is reluctant to invest in long-term research because it is risky, difficult to retain for themselves and, therefore, is not as likely to yield commensurate profits (3:15; 8:51). Thus, the logic is that the Government should invest in research because the returns may often be far greater to an entire industry and to society than it could be to any single company. The argument goes on to reject government support of development activities, except where the Government is the real customer for the products (19; 21). The Government is said to lack knowledge of the market and the motivation necessary to yield economically viable products.

There is a school of thought that advocates government support of certain development activities. Consider the many well-known examples of federal support for development activities in the areas of defense, space, housing, transportation, and nuclear energy. An argument can be made for government development programs where there appear to be very great benefits to society as a whole, but where the rewards may not appear great enough to any commercial firm to warrant large, unhedged, private investments.

The Federal Government continuously faces policy issues on exactly what R&D should be done and who should do it. Every year the executive and legislative branches of the Government must budget for specific R&D programs. The Government must determine the priorities of these programs, based on where the greatest benefits to the nation can be achieved. The use of federal laboratories to accomplish a portion of this work versus use of the private sector is an issue which has arisen in many situations dating back to the early 1800's (1; 22).

AERONAUTICAL R&D

Aeronautics is a basic industry in the United States. The importance of aeronautics to the economy is apparent from some relatively simple statistics. Aeronautical products provide the highest contribution to export sales of all U.S. manufactured goods and are exceeded only by agricultural products (23:1). The United States has manufactured over 80 percent of all the aircraft in operation by airlines throughout the world today (24:20). The net favorable balance of trade in aeronautical products in 1974 amounted to about $5 billion (6:25-26). Thus, aeronautics is vital to the relative strength of the U.S. economy and the soundness of the dollar.

Aeronautics has helped to alter the entire nature of America's commercial and industrial activity. It has enhanced the diversification and geographic dispersion of activities for a huge number of American commercial firms, extending them to national and multi-national dimensions (25:4-7). It has broadened access to customers and suppliers for large and small firms in every industry. American domestic airlines carry about 600,000 passengers a day. This figure is expected to increase by 70 percent over the next ten years (26:223). One can imagine the tremendous positive effects there must be on the economy from the extensive commerce in goods and services conducted daily by air travel. Although the effects on the economy have not been measured, they may well be more significant to the economy than any other factor concerned with aeronautics. However, there is also substantial economic activity directly in aviation. Aircraft sales in the United States totaled $15 billion in 1975 and airline sales amounted to another $15 billion (24; 27:12). Aeronautics currently provides over one million direct jobs (23:1) and an undetermined number of secondary jobs among a vast array of suppliers and related service industries.

The United States is highly dependent upon aeronautics for defense. In fact, the Department of Defense purchased about 1,400 aircraft in 1975 at a cost of $7.2 billion, not including purchases of armament for these aircraft (24:20,31). Indications are that future advances and possibly even increased purchases of military aircraft and air-breathing missles will be required in view of relative advances in Soviet military might (28:40, 44,64-69). Aeronautics provides a major part of the industrial foundation and financial support of the aerospace industry, which also produces the nation's missles and space products. The aerospace industry's products are as basic to the economy, prestige, and defense of the United States as ships were to the great seafaring nations of earlier centuries.

FEDERAL SUPPORT FOR AERONAUTICAL R&D

Past federal support of aeronautical R&D has been mainly for military purposes. The military first employed aeronautics during the Civil War. The civilian Balloon Corps was used by the Union army for battlefield observation and reconnaissance (1:127-128). The War Department supported early experiments on powered aircraft flights conducted by Samuel P. Langley around the turn of the century (1:284-285). A number of government agencies conducted research in aeronautics prior to World War I. However, the National Advisory

Committee for Aeronautics (NACA) was founded in 1915 and provided focused research, advice, and coordination needed to help boost American aviation to the forefront among nations (1:283-287; 29; 30).

The Government's support of aeronautical R&D for military purposes gave the United States its world-wide lead in both military and civil aeronautics throughout the history of aviation (1; 31:6-27; 32). The Federal Government sponsored 45 of the top 51 major technical advances made in American aviation prior to 1972 (32:1). The Military Services directly sponsored 70 percent of all these advances. Civil aviation has relied primarily on military aeronautical R&D in the past to provide a technical basis and developments for commercial aircraft.

Table 1 on the following page shows that federal expenditures for aeronautical R&D amounted to about $3 billion in 1976 (33). The total government expenditure for aeronautics was only about 60 percent of the nation's net export sales of aeronautical products in that year. The federal investment in aeronautical R&D amounted to no more than 15 percent of all the money expended by the Federal Government for R&D (4:2; 24:93; 33). The Department of Defense provided 85 percent of the Government's investment in aeronautical R&D.

It is not difficult to understand why the Federal Government must supply the bulk of funds for aeronautical R&D. The intensity of R&D required to produce the current rate of advances in an industry may be measured by the cost of R&D as a percentage of industry sales. The aircraft and missles industry expended an average of 21 percent of its net sales on R&D between 1961 and 1972 (6:93). This was the highest percentage of R&D expenditures of any of the 15 major industry groups in the United States. It was more than double that of the next most R&D intensive group, which was the electrical equipment and communications industry (6:93). The aircraft and missles industry itself invested 3.5 percent of its net sales in R&D which was typical of all high-technology industry groups. Thus, one could not expect the aircraft and missles industry to provide more of its internal funds for aeronautical R&D without substantially raising its prices to its primary customers. Commercial sales prices are limited by world-wide competitive forces. The Federal Government was the prime customer for missle and space products and for over one-half of the total dollar purchases of U.S. manufactured aircraft in 1975 (24:31). At one end or the other, the Federal Government must pay for aerospace R&D to the extent of roughly 16 percent or more of industry sales.

Table 1

Federal Expenditures in 1976 for Aeronautical R&D
Shown by Performing Institution

SEGMENT OF R & D COMMUNITY	WORK CATEGORY		
	BASIC RESEARCH	APPLIED RESEARCH	DEVELOPMENT
ALL SEGMENTS (Millions $)	$66	$443	$1837
MANUFACTURING AND SERVICE COMPANIES	15%	66%	70%
NON-PROFIT INSTITUTIONS	2	2	2
UNIVERSITIES	30	6	2
GOVERNMENT	53	26	24
TOTAL	100%	100%	100%

National Science Foundation estimates (33)

The aircraft and missiles industry is the most R&D-labor-intensive industry in the United States. It was the second largest employer of engineers and scientists in the United States in 1974, which numbered 70,000 that year (5:10). There were about 90 engineers for every 1,000 employees in the industry (6:93). This was more than twice as large a ratio of engineers and scientists to employees as for any of the other 14 major industry groups in the United States.

CRISES IN AREONAUTICS

The aeronautics industry has been encountering serious problems. The difficulties are expected to grow more acute in the near future unless current trends are reversed by the Government. The U.S. Government has let the financial position and the rate of progress of this basic industry slip very seriously over the last decade. An intense national interest in space during the 1960's sharply diverted attention away from progress in aeronautics. The effects on aircraft R&D programs became even more serious during the 1970's when increased national concern over other social and economic problems resulted in a general decline of interest in national defense or further advancement of America's technological and industrial strengths. The employment of engineers and scientists in the aircraft and missle industry dropped 28 percent from 1970 to 1975. This was four times greater than the average decline of engineers and scientists in other manufacturing industries (4:12). Thus, the federal withdrawal from R&D over the last decade has hit the aerospace industry the hardest.

whatever became of laissez faire principles in speech if not in practice ?

There is a general belief that aeronautics has become a mature industry (34:1). The number of new aircraft prototypes greatly declined over the last two decades. Between 50 and 70 new military prototype aircraft, large and small, entered flight-testing every five years from 1945 to 1960 (34). These figures do not include derivative versions of earlier prototypes or any aircraft modification programs. Many of the military development programs for transports, helicopters, and even light utility aircraft were adapted by commercial manufacturers for civil aviation applications. The space program began in 1958. The number of new military prototype aircraft entering flight-testing dropped, respectively, to 23, 12, and then 13 in each of the following 5-year periods from 1960 to 1975 (34). This reduction was blamed to a large extent on the escalating costs of military aircraft. The reduction in military development programs and possible changes in the nature of government-sponsored research may also have reduced the impact of federal support on civil aeronautical advancements. Civil aircraft manufacturers developed several large wide-bodied jet transports specifically for commercial airlines in the early 1970's. These engineering developments were based on earlier research and technology advancements. However, there have been no new major civil aviation development programs started in the last eight years (26:233).

At the same time, it is clear that many foreign nations, with government support, are continuing to accelerate the pace of their aeronautical R&D programs for military and commercial applications (23:2-3; 34). Foreign aeronautics industries have clearly stepped up their attempts to capture a greater share of the world's aviation markets (23:2). The Soviet Union has continued to obtain increasingly greater advances in military and civil aircraft (28:40,44,46,47,60, 62-66; 34). American aeronautics may be approaching "maturity," but one might well question how much of this maturity has been caused by a failure to provide it sufficient emphasis or to do the right things.

There will be a huge demand for new civil aircraft transports over the next 20 years. Estimates indicate that passenger travel will probably grow at a compound rate from 6 to 8 percent per year and will therefore roughly double during the next decade (35:6; 36:124). The growth of air cargo is estimated at 5 percent annually (36:124). New commercial aircraft will be required to meet this increase in demand. In addition, the airlines will need replacement aircraft with advanced technology to reduce noise, increase safety, cut pollution, and reduce fuel costs. Replacement aircraft will be required. The useful life of current equipment is estimated to be about 20 years (36:119). The average age of aircraft owned by U.S. trunk airlines plus Pan American was calculated to be approximately 7.9 years in 1975 (35:6). It has been estimated that U.S. trunk airlines and Pan American will require new facilities and equipment amounting to a total of roughly $40 billion over the next eight years, $60-65 billion by 1990 (35:6), and $162 billion by the year 2,000 (36:119) Thus, the prospects for civil transport aircraft manufacturers would appear bright if it were not for financial problems.

Unfortunately, the U.S. airline industry is not in a financial position to raise capital to purchase such massive amounts of new equipment (35:7). The airline industry cannot provide deposits or order guarantees to aircraft manufacturers to raise the capital required for new civil aircraft development programs. The difficulty the airlines will have in financing $40 billion of new equipment over the next eight years becomes clear when one realizes that the airlines earned only about $1 billion in the prior seven years (35:6). This industry is already too highly burdened with debt to be a good financial risk under current conditions. Twelve major airlines listed on the New York and American stock exchanges, which are tracked by Media General, had a composite long-term debt-to-equity ratio of 128 percent in the 12 months prior to March, 1977 (37:24). This was higher than 90 percent of 1,500 major common stocks ranked by Media General (37:7). Thus, the airlines would not appear to be a good financial risk unless there is government support of some nature.

The Government has already been deeply involved in the downturn in aeronautics. In fact, there are claims that the Government is responsible for it (35:8). The profit margins of the airlines are influenced by air fares which are currently controlled through government regulation. Air fares have been allowed to rise only 35 percent over the last seven years, while the consumer price index has increased 86 percent (38:60). Regulated railroad fares were allowed to increase 100 percent during this same time period (38:60). The average after-tax profit margin of 12 major U.S. airlines listed by Media General was 1.7 percent of sales over a 12-month period prior to March, 1977 (37:74; 39:6). This ranks below 95 percent of 190 industry groups ranked by Media General (37:91). By way of comparison, the composite profit margins of eight major regulated electric and gas utility groups, ranked by Media General, varied from 5.8 to 24 percent of sales. The composite profit margin for 16 major railroads in the Media General ranking was four times higher than for the airlines (37:91). The composite return on equity of the 12 major airlines was only about 6 percent and the return on total capital was only 2 percent. The regulated utility groups had returns on equity and on total capital that were roughly two to three times greater than the airline group (37:75). Even the railroads had a composite return on total capital that was 80 percent greater than the airline group (37:75-76). The airlines have reportedly been accused of being inefficient by the head of the Civil Aeronautics Board, but the railroads have not yet been termed more efficient (37:91). The airlines currently face the possibility of government deregulation. They fear this will lead to an erosion of air fares under competitive pressures and increased difficulty in raising capital because of the withdrawal of government support (40).

Aircraft manufacturers are also not in a strong financial condition. The large aircraft manufacturers are greatly dependent on the Government for most of their income, which is derived primarily from military aircraft, missles, and space products. The Government holds a monopolistic position relative to these products. It is not only the largest customer for these products, but it also controls all foreign sales of them. In a market where there are multiple suppliers and virtually only one customer, the Government, that customer has a very large measure of control over his suppliers and their profits. The Government can build or destroy the industry. The composite profit margin over a 12-month period prior to March, 1977, for ten major aerospace companies listed on the New York Exchange was 2.6 percent of sales (37:50). This percentage was less than the profit margins of 90 percent of the other 190 industry groups that were ranked by Media General (37:91). The aerospace firms did have a return on equity that was average for the 1,500 companies compared (37:7,50). However, the industry faces huge capital requirements. The Milford committee of Congress pointed out that "The costs of developing new aircraft and engines are approaching the net worth of individual manufacturers, seriously inhibiting such projects" (23:2).

Members of Congress and executive agencies are currently considering ways of increasing government support for U.S. airlines and for aeronautical R&D programs (23; 35). A substantial body of opinion favors such action (12; 23; 38; 41; 42; 43:41), but there are also opposing viewpoints. Many members of Congress and the executive branch favor removal of supportive price regulation of the airlines (40). These viewpoints are based on a Bureau of the Budget study that claimed air fares have been too high. The expectation is that lower fares would increase airline profits by increasing the passenger volume.

There is also a contention that aircraft manufacturers have earned ". . . rates of return on total investment on military aircraft projects . . . substantially in excess of the level required to allow these firms to attract capital" (18:11). Other opposing arguments are that the Government has stimulated the demand side for new aircraft through its regulatory powers and tax structure for depreciating commercial aircraft in use by the airlines (18:12). Arguments have also been advanced that the Federal Government should not increase support for any R&D and particularly, not for aerospace, because a decrease in the demand side should result in a decrease in the federal funding supply side (10). There are those who believe that aerospace firms should be allowed to fail (10:272-273). Some authors have opposed government support to the aircraft and missles industry for R&D based on the fact that the extensive R&D required by this industry and for the electrical equipment industry, which also receives substantial federal support, are not reflected either in commensurate increases in financial profits to these industries or increases in their productivity (11:217; 12). Most of these opposing arguments are clearly not valid in view of the facts discussed earlier.

RECENT STUDIES ON AERONAUTICAL R&D

Aeronautical R&D has been receiving more attention and increased study during the decade of the 1970's. Recent studies have addressed the impact of aeronautics on the nation's economy and welfare, current problems and future prospects for civil aviation, the contribution of military aeronautics to the progress of aviation, the Government's role in regulation and support of aeronautics, projected future aeronautical advancements, and the potential offered by aeronautical R&D in specific technical areas (23; 25; 28; 32; 41; 42; 44; 45; 46). These studies recommended that various federal agencies support a considerable amount of research, technology advancement, and development in aeronautics. A logical question then arises as to who should conduct all this work for the Federal Government. This issue has already surfaced as an intense topic of discussion in many previous publications (for example, 41; 42; 45:Appendix B; 47 and elsewhere).

Wide ranges of opinion have been expressed by various aeronautical R&D leaders. However, there have been no prior systematic investigations of rationale for government use of the various segments of the aeronautical R&D community or to reveal the relative strengths they each have to offer.

AERONAUTICAL R&D INSTITUTIONS

How important is it to understand the institutional structure and relative strengths of the various segments of the aeronautical R&D community? Donald M. MacArthur, Deputy Director of Research and Technology in the Department of Defense, pointed out during House committee hearings in 1968 that it is not possible to examine even federal laboratories in a meaningful way

> . . . unless we place them in proper prospective, with respect to the other four types of performers we depend upon in the DoD to accomplish our mission. . . . Each of these organizational types (industrial firms, universities, non-profit institutions, and federal contract research centers) has a relatively unique, although not mutually exclusive, role to play in satisfying DoD requirements (48:3-4).

One of his successors, John L. Allen, pointed out in 1974 that

> . . . the differences between in-house laboratories, commercial industry, and the academic community lead to differences in their capabilities that must be recognized and exploited for a maximally effective RDT&E [research and development] process (49:3).

An economist, Robert Gilpin, stated in a report for the Joint Economic Committee of Congress in 1975 that

> . . . [The] contrasts and differences among the various types of R and D should be primary considerations in the development of a national policy towards R and D. They should determine the appropriate role of the various sectors of the R and D enterprise (university, government, and industry). Unfortunately, . . . too frequently the comparative advantage of each sector has been neglected in the fashioning of national policy for R and D (8:36-37).

Gilpen asserted that part of the reason for Britain's decline in technology has been that " . . . the British have failed to integrate sufficiently the three estates of science and technology: universities, government, and industry" (8:63).

H. Guyford Stever, former Director of the National Science Foundation and Science Advisor to the President, pointed out in a paper submitted to Congress in 1976 that two of the four things that Government must know in order to define an appropriate role of Government in aeronautical research and development are

> . . . (1) to understand the institutional structure of the aviation industry, (2) to understand some characteristics of aeronautical R&D . . . . (50:430).

Nevertheless, there has been no prior attempt to make a comprehensive and systematic assessment of these factors relative to each other.

Serious questions already have been raised and many actions taken in regard to the roles performed by various R&D institutions for the Federal Government. They have all affected aeronautical R&D. Congressional hearings and investigations in 1969-1970 questioned if it was appropriate for manufacturing companies, primarily aerospace firms, to receive government support for Independent Research and Development (IR&D) (7:41-42). Legislation was proposed to eliminate such support. In the early 1970's, many individuals on university campuses attacked the role of universities in performing defense-related R&D on university campuses. Subsequent actions by many universities, and by Government itself, resulted in an alteration in the character and extent of such activity in many fields. Proposals were made by a Presidential commission in 1970 possibly to have private contractors operate some Department of Defense in-house laboratories (51:88). A later study in 1975 recommended that government laboratories should be reduced about 15 percent from their 1974 levels (47). This recommendation was based on historical funding relationships and policy decisions on the roles of government laboratories relative to the private sector. Substantial reductions in government scientists and engineers began in 1975. Congressional criticisms and pressures from other private firms led to questioning the rationale behind the Department of Defense's use of captive Federal Contract Research Centers, which are non-profit R&D institutions (52). The Department of Defense substantially reduced its use of this type of institution in 1976 (52:17).

The Office of Management and Budget of the executive branch of the Government has reportedly been exerting pressure on the Department of Defense and the National Aeronautics and Space Administration to convert its in-house activities into contracts with the private sector and to decrease the number of government personnel within these agencies (53). The policies of the Office of Management and Budget have long stipulated that cost should be the major factor in determining whether work is accomplished by the Government itself or under contract (53; 54). But, is cost the only factor that differentiates aeronautical R&D institutions in regard to conducting work for the Government?

DISTINGUISHING FEATURES OF R&D INSTITUTIONS

Aeronautical R&D institutions may be divided into five identifiable categories: manufacturing companies, service R&D companies, non-profit institutions, universities, and government laboratories (Appendix B, pages 174 to 176). However, does anything really differentiate these types of organizations? After all, they can all hire engineers, scientists, technicians, and machinists. An extensive body of literature published in recent years shows that organizations differ as a result of their internal and external environments (for example, 55; 56; 57; 58). The internal environment includes organizational structure, management style, work patterns, interactions between organizational units, communications, personnel practices, and organizational development. The external environment consists of the demands placed on the organizations by products and services required by their markets, necessary interactions with customers and suppliers, the nature of competition, the economy, governmental actions, community relations, and such factors.

The contingency view of organization and management (for example, 55; 59) stresses the importance of obtaining a three-way match among the members' propensities, the internal environment, and the external environment. It has been shown that different types of organizational climates and management methods are required in order to conduct different kinds of work effectively. For example, Jay W. Lorsch and John J. Morse (55) found that different management styles and varying degrees of feedback were necessary, depending upon the nature of the work and the degree of uncertainty inherent in the external environment. In research organizations the external environment is highly uncertain. The most effective research laboratories were found to be those utilizing less structured organizations, less emphasis on communications, slower feedback, and more participative management styles. The exact reverse was found to be true for effective manufacturing organizations where the external environment was highly certain and the nature of the people was different than in the research organizations. It therefore requires different types of organizations and management methods to best accomplish different types of work.

The R&D institutions in the United States have developed different internal organizational climates to fit their situations. Studies by Howard M. Vollmer (57), Albert Shapero, and others (58) at Stanford Research Institute have revealed extensive categorical differences among the internal environments of government laboratories, universities, non-profit institutions, contract research centers, and industrial establishments. However, Vollmer (57) presented evidence that the internal environments sometimes even differ among the same types of R&D institutions in different industries. Thus, it is important to relate roles of R&D institutions to a specific industry, because the results may not hold true for other industries.

There are clearly different external environments for all of the institutions engaged in aeronautical R&D. Universities basically are engaged in education and must be responsive to the students' needs and time schedules. Manufacturing companies depend primarily upon the sale of their products and must be responsive to the market and their stockholders. Service R&D companies are not dependent upon sales of manufactured products and therefore must address their efforts mainly to the market for their technical services. They are also under pressures from their stockholders to produce profits. Non-profit R&D institutions have very similar external environments to those of the service R&D companies except they do not have to show a profit for stockholders. Some non-profit R&D institutions, called Federal

Contract Research Centers, are partially or totally captive organizations of the Government. They are under less competitive pressures than other organizations in the private sector. Government laboratories do not operate in situations that are as competitive as those for R&D organizations in the private sector. In fact, government laboratories control a substantial portion of the funds expended on research and technology in the private sector. However, each of these groups must coordinate with and be responsive to their customers. The possible degrees of coordination and types of interactions with their customers are different for the various R&D institutions. Hence, there are obvious dissimilarities in the external environments as well as in the internal environments of the institutions engaged in aeronautical R&D and one might expect that these factors will influence their work.

PRIOR STUDIES ON STRENGTHS OF R&D INSTITUTIONS

There have been no comprehensive systematic studies to examine the relative strengths of aeronautical R&D institutions and to examine underlying rationale for government use of particular institutions. Vollmer (57) conducted a study in 1965 during which he sampled scientists and research managers and obtained a cross-evaluation of the relative prestige of several segments of the R&D community. This study also presented data on the willingness of different types of organizations to communicate their results outside their own organizations. Vollmer's investigation sampled the aerospace industry, but it was limited to people in the fields of biology, chemistry, mathematics, and physics, which were not representative of the major technical disciplines in the field of aeronautics (60).

In 1970 E. M. Glass reported peer ratings for laboratories in the Department of Defense (56:13). The relative performance of these laboratories was assessed by comparing the input to the laboratories relative to their output. The input to the laboratories was expressed in terms of funds, equipment, and property. The output was assessed from the peer ratings, papers, and patents. This investigation of DOD laboratories did not obtain any comparisons related to any other segment of the R&D community. It also did not compare DOD laboratories relative to their work in aeronautics.

The Department of Defense carried out an assessment of military service laboratories from 1974 to 1975, during which it conducted a survey only among members of the DOD staff (47:c-1 to c-12). The survey provided data on the staff's opinion regarding whether more or less work in specific technical areas should be done under contract or in DOD laboratories. It determined the staff's attitude regarding the quality of work conducted by DOD laboratories for categories from research through development. As part of the investigation, the Air Force surveyed 17 internal Air Force "customers" for Air Force laboratory products. Data were reportedly obtained regarding the competence, responsiveness, and objectivity of laboratory personnel in relation to categorically similar organizations outside the Air Force (47:24). The Department of Defense laboratory utilization study presented comprehensive data on personnel, contracting trends, and a very broad specturm of Department of Defense activities. This study presented DOD rationale for use of various R&D institutions. However, it did not assess the relative strengths of all the segments of the R&D community as they might be viewed from vantage points outside the Government.

A Department of Defense task force conducted a study of non-profit Federal Contract Research Centers in 1976 (52). Survey questionnaires were submitted to nine such centers operating under the Department of Defense. The task force conducted interviews with people in these centers and in sponsoring organizations. The results were discussed in the final report of the task force but the data were not reported. Furthermore, this study essentially focused on a single segment of the R&D community. The study did not evaluate the roles of the other R&D institutions or assess attitudes in the other institutions regarding their relative strengths for conducting work for the Federal Government.

A NASA committee conducted an interesting study from 1975 to 1976 entitled "The NASA Outlook for Aeronautics" (45). Among many other things, it sought to define NASA's mission in aeronautical research, technology, and development (45:Appendix B). The committee obtained outside viewpoints by personal interviews, letters, and surveys covering 38 industrial organizations, 9 leaders in universities, 10 leaders at headquarters level in the Department of Defense, and leaders from 6 other governmental agencies in Washington. The NASA committee interpreted and presented general consensus statements of the comments and also ranges of opinion. This investigation provided useful information on how various other organizations and outside leaders viewed NASA's role in aeronautics. The committee then formulated its own view of NASA's role in aeronautical R&D.

The earlier investigation into roles for NASA revealed the need to address the NASA laboratories within the total context of all the nation's aeronautical R&D institutions. In addition, it appeared necessary to move the inquiry into the realm of quantitative determinations of such subjective judgments in order to gain more specific information on the extent and intensity of the opinions of aeronautical R&D leaders. It was clear that more highly structured techniques would be needed to examine intrinsic strengths, uncover supporting rationale, and evaluate the roles of all aeronautical R&D institutions relative to carefully defined categories of work.

CURRENT INVESTIGATION

relationships among strengths?

The specific purpose of the current investigation was to determine what relationships, if any, exist among the relative strengths of the nation's aeronautical R&D institutions in regard to conducting aeronautical R&D for the Federal Government. It was conceived to provide comprehensive, quantitative evaluations of rationale for every segment of the aeronautical R&D community, as viewed by leaders from all of these institutions. Special methodology was devised to surface and cross-evaluate relevant rationale. The investigation could not logically be confined within the usually desirable constrictions of testing a relatively small number of discrete hypotheses. The results are therefore extensive in nature. They can be used as a virtual handbook of judgments for specific problems in a wide variety of pertinent issues. The information obtained in this investigation should be used in formulating government policy on aeronautical R&D. The results also can be employed by aeronautical R&D organizations, in the public and private sectors, in formulating long-range goals and strategic plans.

Chapter 3

METHODOLOGY

The purpose of this investigation was to determine what relationships, if any, exist among the relative strengths of government laboratories, manufacturing companies, service R&D companies, non-profit R&D institutions, and universities in regard to conducting applied research, basic research, technology advancement, and development in aeronautics for the Federal Government. A total of 25 of the nation's leaders in aeronautical R&D was selected from among the members of the American Institute of Aeronautics and Astronautics. Five leaders were selected from each of the segments of the aeronautical R&D community to provide equal weighting to judgments on rationale that supported each segment. Analysis methods were devised to reveal the degree of agreement among leaders within each group, between specific groups, and for the total sample of all 25 participants.

The investigation was divided into two parts. The first part consisted of a survey questionnaire to obtain judgments on factors that were hypothesized as being important, lent themselves well to written survey questionnaires, and were not appropriate to conference discussions. The second part of the investigation consisted of a workshop. In the workshop, the participants had the opportunity to introduce and cross-evaluate rationale for government use of each type of aeronautical R&D institution. The workshop employed a new conferencing technique that used successive evaluations by homogeneous sub-groups, mixed sub-groups, and individuals. The technique was devised during this investigation in order to stimulate discussion, improve communications, and extract quantitative information on group consensus judgments on highly controversial topics. The technique was formulated to secure subjective judgments from groups that have intrinsically competitive objectives, unequal power over each other, and a degree of mutual dependence.

DEFINITIONS

Definitions present a major problem in obtaining subjective judgments of the strengths of the various sectors of the aeronautical R&D community and rationale that tend to support government use of those institutions. The various *strengths* hypothesized in the survey questionnaire and those that emerged from *rationale* obtained during the workshop are operationally defined, respectively, by the questions presented in the questionnaire (pages 178-188), the statements made in the workshop (Tables 10 through 32), and the related measurements.

ORGANIZATIONS

There are three general types of organizations defined in this publication which are involved directly or indirectly in aeronautical R&D.

Aeronautical R&D institutions. The terms *segments of the aeronautical R&D community* and *aeronautical R&D institutions* have identical meanings. They refer to organizations that actually conduct original aeronautical R&D for the Federal Government. These organizations were divided into five relatively homogeneous groups: *manufacturing companies* (Man Cos), *service R&D companies* (Serv Cos), *non-profit R&D institutions* (Non-Profs), *universities* (Univs), and *government laboratories* (Gov Labs). They are defined in Appendix B on page 174. The essential differences in the definitions of these institutions stem from variations in their principal products, services, and ownership structures. It is important to note that the terms *government laboratories* and *NASA laboratories* refer only to original, in-house, aeronautical R&D conducted by these laboratories.

Government test centers. The primary tasks of *government test centers* are to conduct ground and airborne tests for other organizations. They perform relatively little original aeronautical R&D other than developing testing facilities.

Government funding organizations. The *government funding organizations* conduct little or no original R&D. They are management organizations that provide funds to the performing institutions. Appendix B contains a definition of this type of organization on page 175. Government funding organizations would include such organizations as system project offices (SPO's), the Air Force Office of Scientific Research, or any organization that simply contracts for and guides work. However, they would also include organizations, at higher government levels, that provide R&D funds to government laboratories.

ALLOCATION OF EXPENDITURES

Government contract expenditures that are principally to help government laboratory personnel conduct original R&D were attributed to the government laboratories (Appendix B, page 174). All expenditures under government contracts to other institutions were attributed to the institutions that conducted the original R&D, even in cases where the government laboratories issued the contracts. Government funds for Independent Research and Development (IR&D) and the resultant efforts by private firms were not included within the scope of this investigation. These funds fall under the discretionary control of the firms that receive them. These firms use the government funds for IR&D in much the same manner as they invest their own internal funds, which also were not considered in this investigation.

CATEGORIES OF WORK

The aeronautical R&D process was divided into four categories of work: *basic research, applied research, technology advancement,* and *development*. These categories are defined by the objectives used to justify the work and the technical nature of the work. The aeronautical R&D process actually consists of a continuous spectrum of overlapping activities that extend from basic research through final product development. The nature of the work and the information required to do it vary markedly from one end of the spectrum to the other. In general, the breadth of the objectives diminishes and the investments increase as activities progress from basic research to final product development (4:6; 44:50).[1] Nevertheless, it is highly desirable to create logical definitions of *categories of work* to describe the steps in the R&D process. They are very useful for management, planning, and budgetary purposes. The definitions used in this investigation are presented in Appendix B, pages 174 to 176.

Immense problems and misunderstandings have been created by a proliferation of meanings of terms commonly used to divide the R&D process into various categories. The American Institute of Aeronautics and Astronautics published a report in 1975 which contained an excellent discussion and comparison of 13 current sets of definitions. This publication includes six official sets of definitions used by different government agencies (44:49-54). Figure 1 illustrates the relationships between the current definitions (Appendix B) and two other logical sets of definitions frequently used by the Federal Government.

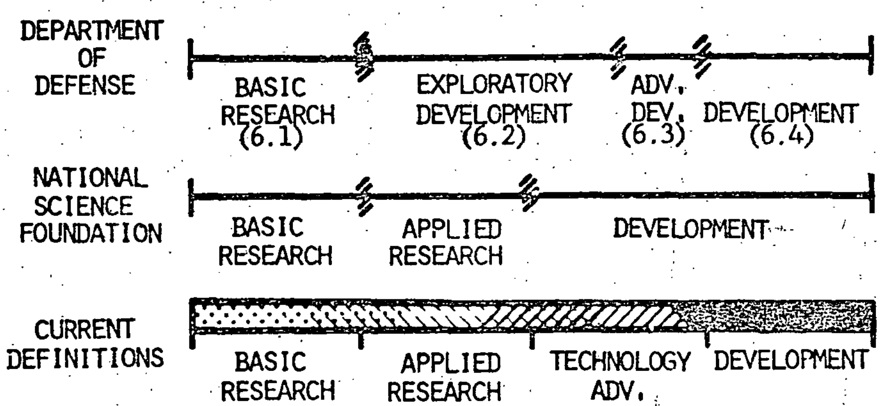

Figure 1: Definitions in the R&D Spectrum

[1]Notation (4:6; 44:50) means Reference 4: page 6 and Reference 44: page 50.

ORIGINAL PAGE IS OF POOR QUALITY

Substantial communications problems result from the many terms used in Government to describe its categories of R&D. No official published set of definitions for the categories of work used by NASA for its aeronautics programs could be located for this study. It also was not possible to determine from NASA's in-house and contract work, conducted under these NASA categories, how the categories related to the spectrum of work shown in Figure 1. A Senate staff report in 1976 also noted that "It is difficult to gauge the extent of NASA's work in basic aeronautics using the current budget breakdown" (53:23). This problem is also reflected in much of the literature on NASA's aeronautics programs which interchangeably use the terms "research," "research and technology base," "technology," and "R&D." Department of Defense officials have also often used the term "technology" interchangeably with "applied research," "R&D," and "development." Organizations in both agencies have used hybrid terms to describe similar things. Experimental aircraft built just to test aeronautical innovations or gain experience in new flight regimes have often been called technology demonstrators, hardware demonstration programs, concept demonstration programs, demonstration aircraft, experimental prototypes, research vehicles, or research aircraft. Here the words "research," "technology," and "experimental" often are used interchangeably. From these terms, it might appear that the efforts fall at different points in the R&D spectrum (Figure 1). The current set of definitions on pages 175 to 176 place such programs well within the technology advancement portion of the spectrum and often toward the development end of it. Hence, definitions of the categories of work present a difficult problem in discussing aeronautical R&D for the Federal Government.

PARTICIPANTS

A total of 25 aeronautical R&D leaders was selected from among the membership of the American Institute of Aeronautics and Astronautics. Five participants were selected from each of the five segments of the aeronautical R&D community. This selection was made to obtain equal weighting of points of view from each of the five types of aeronautical R&D institutions. The participants and their organizations are listed on pages vii and viii. Profiles of the participants' backgrounds and a description of the author's background are presented in Appendix A on pages 166 to 171.

The following criteria were used by the author in selecting each participant:

1. Leadership--prime R&D management position in an aeronautical R&D institution and/or an outstanding reputation for original aeronautical R&D.
2. Views on subject--unknown to author and sponsor.
3. Institutional affiliation--equal representation.
4. Organizational affiliation--representative sample of technical products and services.
5. Geographical location--national dispersion.

The author was acquainted with only three of the participants prior to the study. Their views on the subject were not known.

There were four problems regarding the representation that may have had some influence on the results of this investigation. First, the leaders from the non-profit R&D institutions actually represented two separate factions. Some leaders came from non-profit institutions that were captive organizations to the Government and others came from more independent organizations. Observations from the workshop revealed some tendency for these two groups to differ because of their contrasting situations. Second, one representative in the non-profit group came from an organization primarily engaged in space activities, although he previously had been known for his work in aeronautics. Third, the representation from government laboratories included members of all the major government agencies in aeronautical R&D except the Federal Aviation Agency. This omission probably made a difference in regard to government civil-aviation R&D activities which deal with airline traffic, airports, and safety. Fourth, there were no representatives from the helicopter industry, although there was an Army representative familiar with helicopter technical problems.

Some caution is also warranted in regard to possible misinterpretations of the results of this investigation. Most of the participants came from particularly high levels of management in aeronautical

R&D organizations (pages vii and viii). Their judgments may not necessarily have been representative of lower level engineers, scientists, or managers in aeronautical R&D. For example, Vollmer (57) reported considerable differences, in many cases, between viewpoints expressed by researchers and those given by research managers. There also could have been differences between the participants' judgments and those of younger, less-experienced engineers and scientists. The views expressed by all participants, as a group, also may not have been representative of those that would have been obtained by proportional representation from each segment of the aeronautical R&D community.

CONVENTIONAL ADVISORY AND CONFERENCE MECHANISMS

Government and private organizations engaged in aeronautical R&D have sophisticated techniques for conducting R&D. However, they tend to use conference and advisory group methods that are old, simplistic, and often ineffective. The most common method is the group "meeting," which approximates the open forum of the ancient Greek civilization. In a forum, a group may arrive at a consensus by voting in Greek citizen style or the chairman might make a decision in the manner of the early kings. There are common hybrid versions of these two group decision processes that are commonly used in the aeronautical R&D community. One or two people may prepare written summaries of group consensus judgments, which might be altered by members of the group or higher authorities. This method does not convey the extent of agreement or disagreement among the members of the group. Important information can also be lost in the process of interpretation.

Open forums have been plagued by many well-known defects that can lead to poor communications and faulty decisions (61:6,86; 62:1; 63:177 to 190; 64). They include domination by strong eloquent personalities, public conflicts triggering rebuttal-oriented listening, embarrassments of publically revising positions, majority pressures, interference from irrelevant material, over-politeness, authoritarian manipulation by organizers or chairmen, personal perils of free speech, pecking order communications, and imprecise methods of establishing a group consensus.

The approaches advocated for improving conference communications and group decisions fall into two categories. They either attempt to improve human behavior (for example, 65; 66) or they attempt to improve the basic structure of the conference method (61; 63; 64). Perhaps the greatest potential is offered by seeking ways to improve the conferencing structure since human behavior is extremely difficult to change on a large scale. Some prior methods have yielded improvements in the structure of open forums in appropriate situations. They include brainstorming, sub-group discussions, posting, and others (64; 67). However, many of the major problems associated with open discussions best can be solved by providing a degree of anonymity. Secret balloting has been used to improve decisions at the end of open forums. Closed executive sessions have also been used by government advisory groups. However, the closed vote at the end of an open forum does not aid the early part of the communication process and a closed executive session is merely an open forum with more limited participation.

Written survey questionnaires have been used to provide strict anonymity, reduce irrelevant communications, and increase economy (68; 69). This relatively old and useful method of gathering opinions is limited by the fact that it provides only one channel of communication. It does not allow the participants themselves to exchange information, ideas, and viewpoints in order to explore and upgrade judgments. The survey questionnaire is also subject to many possible errors in construction including omission, vagueness, ambiguity, and biased wording.

The impersonal survey-questionnaire technique provided the foundation of the Delphi method which was invented, not by the early Greeks, but by the Rand Corporation around 1950. The Delphi method has hundreds of variations but they all basically provide for anonymous communications by the use of successive rounds of questionnaires (61). After each round, the participants receive the results summarized in statistical form and perhaps written information from the responses. The participants may then modify their views after rethinking the situation. This procedure has been found to lead towards a convergence of group opinions. The Delphi method has been criticized severely for its high participant dropout rates, tendency to produce conformance to majority opinion, lack of proof of validity, and loss of group creativity that might be possible through personal interactions (67). There were other criticisms attributed to the Delphi method that were no more than incorrect applications of analysis methods, sampling procedures, statistical techniques, and reporting requirements (67). They were not fundamental to the basic characteristics of the Delphi method as a conferencing technique.

SEGMENT ANALYSIS

The methods used in this investigation were constructed to provide quantitative information on the points of view of the leaders from each of the segments of the aeronautical R&D community and the combined opinions of all 25 participants. In a criticism of past use of expert opinion, H. Sackman suggested that all future methods should employ techniques that allow identification of sub-groups and analysis of their opinions (67:26). Sackman cited prior studies for the Government where extensive group biases were suspected, but which were difficult to trace because of the methods employed. Many people in Government expect advisory groups to be above biases. One published study reported that advisory groups composed of members of certain Air Force aeronautical R&D organizations were completely objective in giving advice in a Delphi study (70). This study supposedly showed that they even provided judgments contrary to the goals of their own organizations. The proof given left some room for doubt because the impacts on future organizational goals were not carefully identified and the statistical significance of the comparisons was not computed.

The current investigation employed segment analyses for several reasons. It was hypothesized that leaders from the same types of aeronautical R&D institutions would tend to have common views regarding the relative strengths of all segments of the aeronautical R&D community. Another hypothesis was that many of these views would be shared by leaders from all the aeronautical R&D institutions. If the segment analyses showed this to be true for certain opinions, then these viewpoints might be accepted as postulates. However, aeronautical leaders from the different institutions were also expected to disagree on many of these issues. In these cases, the segment analyses would provide the opportunity to select the set of "advisors" that seemed most likely to have made the best judgments. In addition, the sub-group analyses would reveal sub-group viewpoints that might explain reasons for different attitudes that one might encounter in dealing with people from these institutions in the future.

SURVEY QUESTIONNAIRE

A survey questionnaire was prepared and mailed to all 25 aeronautical leaders prior to the workshop. The questionnaire is given in Appendix C, pages 178 to 188. It included institutional strengths that were hypothesized as being significant but which did not lend themselves well to discussion at the workshop. The survey questionnaire started the participants' thinking about the problem and the related definitions. However, the results were not fed back to the participants nor was the survey discussed during the workshop. The intent was to limit the impact of the questionnaire on the workshop. The participants completed matrices on funding in the questionnaire and at the end of the workshop (Appendix C, pages 187 and 188).

The questionnaire was prepared in about two months. It was completely rewritten seven times and was pre-tested on six engineers, a secretary, and a housewife. The estimated time to complete it was 45 minutes. A total of 22 participants returned the completed questionnaires by mail before the workshop, as requested. These questionnaires were anonymously returned, identified only by segment of the aeronautical R&D community. The other three participants personally handed in the completed questionnaires at the start of the workshop.

WORKSHOP AND TRIBUTARY TECHNIQUE

The *tributary technique* was devised to provide a conference structure for the workshop. The technique was designed to establish a flow of information somewhat similar to the way that tributaries develop from their own sources, successively interact with other tributaries, mix in rivers, and flow into the oceans. The technique was devised for conferences where the participants belonged to organizations that did have an overall common objective, where there were various degrees of mutual dependence among sub-groups. However, the technique was most specifically designed for situations where these groups had, at the same time, strongly diverse, conflicting, and often competitive objectives. It was for high-threat environments where many participants might initially feel that individual free speech could adversely impact their own organizations. The technique was devised for difficult topics that required exploration, examination, and highly subjective judgments by qualified people. It was for topics that required clear consensus judgments by groups, rather than possibly divergent individual innovations.

PRINCIPLES OF TRIBUTARY TECHNIQUE

The tributary technique was based on nine main principles related to group dynamics.

Interesting group discussions. The tributary technique was devised for group discussions combined with impersonal communications, as opposed to the completely impersonal approach used in the Delphi method. The reportedly massive dropout rates in the Delphi process are indicative of frustration or a loss of interest (67:52). In such cases, one cannot control the type or extent of participation. The current method was devised to create an exciting atmosphere. There is reason to believe that people think and work best under such conditions. Prior studies indicated that small groups, of about six members, with internally free discussions were most likely to reach consensuses (64:193). This concept was found to be valid, independent of the skill of the leaders. These prior studies indicated that periods of 20 to 30 minutes for intense group discussions were best, although some discussion methods dealt with brief topics in only 6 minutes (64).

Highly structured steps. The tributary technique provided a very highly structured conference. In fact, the conference structure was used to replace the role usually assumed by a chairman. Neither the author nor the sponsor had any control whatsoever over the participants' activities within the framework of the conference structure. The expectation was that the conference structure would also increase participant teamwork, reduce interference from extraneous material, increase efficiency, and increase the participants' satisfaction. Some earlier studies indicated that groups are, in general, more satisfied with conferences that have a good deal of procedural structuring, or control, than they are with meetings that are less orderly (64).

Graduated tasks. The entire process was divided into a series of graduated tasks in order to help the participants progressively make more difficult decisions. The tasks and the goals were carefully defined for each set of discussions. The results at the end of each stage were self-contained and logically complete. The interaction process was planned so that every group's output, at every stage, was rapidly reviewed by a peer group. The members of each group had the ability and the power to make decisions and complete their tasks at each stage of the process. Earlier studies in group dynamics indicated that group productivity increases when the participants know that they have the power to resolve the problem that they are given (64).

Rethinking and feedback. The procedures were devised to give each participant up to three chances to change decisions. A participant could alter his decisions each time without anyone else realizing that he was revising his position. The rethinking process was also designed to contribute to the participants' thought processes and to allow them to move on to increasingly difficult decisions. This procedure was expected to yield a convergence in viewpoints. There was some prior evidence from a Delphi study that just rethinking decisions played a strong part in the convergence process that took place in the Delphi method (62). Feedback was also used in the tributary technique. All conference methods make headway by providing feedback in some form. The tributary technique was structured to yield timely and complete feedback on sub-group consensus viewpoints.

Time pressure. The time for each step purposefully was set at a level that would create pressures on the groups. Studies at the University of Michigan on group dynamics have shown that "The more urgent the problems, the more productive the group" (64:63).

Graduated confrontation. The conference was structured to limit direct confrontations between participants from dissimilar groups, until all homogeneous groups had an opportunity to carefully consider all viewpoints. A series of steps provided indirect communication between homogeneous groups prior to mixed group meetings.

Constructive competition. The idea was to channel the natural sense of competition into constructive contributions. The tributary technique was based solely on positive inputs followed by quantitative evaluations of those inputs. Each sub-group was to be challenged, by a sense of competition, to improve on the inputs of other groups.

Anonymity. The intent was to increase the freedom to communicate by submerging individual judgments in homogeneous sub-group opinions. The maximum threatening exposure was in mixed group meetings that followed homogeneous sub-group meetings. However, in the mixed group meetings, each participant had the option of impersonally stating viewpoints as the opinions that came out of his homogeneous group meetings.

Quantitative output. The tributary technique was devised to provide complete quantitative output on group consensus judgments at the end of every phase of the process. Groups and individuals had to make quantitative decisions which provided focus and task-oriented behavior.

TECHNIQUE DEVELOPMENT AND PREPARATIONS

The tributary technique was designed in conceptual form. The process was planned for five homogeneous sub-groups considering four categories of work. The entire workshop was to be limited to a single day.

Test groups. A model of the tributary technique was devised to test the whole process by using two homogeneous groups and two categories of work. The model workshop was conducted with five participants from one government laboratory and five participants from a service R&D company. The participants in the test groups were interviewed, as a group and individually, after the model workshop. Information was obtained from the test groups on the time required to complete the tasks, the clarity of the instructions, communications difficulties, individual attitudes, and the efficiency of the procedures. The tributary technique and its implementation were substantially modified based upon this information.

Training the workshop observers. The day before the conference, five observers were instructed on their functions. Each group discussion session in the conference was to have one observer and one recorder. The observer's functions were to enter formulations of tentative group viewpoints on a blackboard, comment on clarity of the statements, transfer group decisions to a flip chart, keep the group on time, and interpret procedures. The observers were instructed not to participate in the discussions in any manner nor attempt to act as meeting chairmen. They were shown how to handle potential difficulties that had arisen in the earlier test-group sessions. They rehearsed all procedures during practice sessions. The observers were as follows:

Stephen H. Achtenhagen
Professor
School of Business
San Jose State University

William Brickner
Professor
School of Business
San Jose State University

John R. Chirichiello
Associate Director
Industry Studies
National Science Foundation

Stewart E. Fliege
Professor
School of Business and Management
Pepperdine University

Dennis D. Schiffel
Group Leader
Effects of Public Policy on S&T
National Science Foundation

None of the observers had ever worked in the field of aeronautics nor had they ever had any affiliations with organizations engaged in aeronautical R&D.

OPENING SESSION

The agenda followed during the workshop is given in Appendix C on pages 189 to 191. The author took 10 minutes of the opening session to review and discuss a list of definitions which were distributed as handouts (Appendix B, pages 174 to 176). The roles of the observers in the sub-group sessions were explained. The participants were informed that no judgments would be traceable to individuals. It was considered very important not to reveal the entire process in advance which might have interfered with sequential decisions and biased group actions. Only the procedures and tasks for the homogeneous sub-group sessions were outlined at the opening session.

HOMOGENEOUS GROUP SESSIONS

The participants were divided into five sub-groups. Each sub-group consisted of representatives of a single segment of the aeronautical R&D community. The homogeneous sub-groups met in separate rooms.

Rationale development: self-justification. Each sub-group was asked to indicate, on a flip chart, as many as four primary reasons why the Federal Government should use its type of R&D institution to conduct each category of aeronautical R&D. In other words, each sub-group would submit a maximum of 16 self-generated statements of rationale why the Government should use its type of institution to conduct all four categories of work from basic research through development. Each statement of rationale was to be a sentence that contained a single reason. The statements of rationale did not have to be unique to just one institution or a single category of work. The same rationale could be applied to more than one aeronautical R&D institution and to multiple categories of work. Tentative statements were first formulated on a blackboard. The observer transferred a final statement to the flip chart when three or more of the five sub-group members agreed with it (for example, see Appendix C, page 192. The recorder then entered the rationale statements on a hand-held form (Appendix C, page 193. The time allotted for the first session was 1 hour.

Rotation, review, and expansion of rationale. The sub-groups then sequentially rotated rooms for each of the following sessions. The same room was always used for consideration of rationale related to the R&D institution whose representatives had originally occupied the room. The observers, recorders, and flip charts remained in their original rooms. Hence, each reviewing group read the rationale statements left on the flip chart by the prior groups. The first task assigned to each review group was to enter on the flip chart, new statements that either supported, clarified, or corrected rationale for government use of the R&D institution that had initially occupied the room. The review group was not permitted to physically alter the previous statements appearing on the chart or to enter negative statements. The process used by each reviewing group in formulating, agreeing upon, and recording the new rationale was exactly the same as had been used in the initial session. Next, the reviewing group again examined the previous rationale to determine if it considered any of the rationale to be completely invalid. When four out of five members of a review group agreed upon such a judgment, the recorder then noted it by placing a blackball (●) on the hand-held rationale sheet (Appendix C, page 193). The recorder also noted which homogeneous group entered each statement of rationale by using a plus (+). This information did not appear on the flip chart and was not available to the reviewing groups during these homogeneous group sessions. There was only one round of rotation. Therefore, none of the homogeneous sub-groups had an opportunity, during these sessions, to see any of the new rationale entered on its original flip chart. The single-round approach was used in order to avoid concerns of competitive counter-actions that might have followed the first round of reviews. However, the one-round approach meant that none of the sub-groups could evaluate all of the new rationale entered by all reviewing groups on the flip charts of every other R&D institution. The time allowed for each review session was 25 minutes. The observers indicated that perhaps 10 additional minutes should have been allowed for the last session because of a substantial accumulation of rationale statements.

FEEDBACK ON RATIONALE

The rationale statements and judgments from all the prior homogeneous sub-group sessions were next distributed to all participants. This distribution was accomplished by reproducing the accounts maintained by the recorders on the hand-held rationale sheets (Appendix C, page 193). The participants were next given instructions, in a general session, for the mixed group sessions which followed.

MIXED GROUP MEETINGS

The participants were then divided into five mixed groups. Every mixed group had one person from each of the five segments of the aeronautical R&D community. Four of these groups each considered a different category of work: basic research, applied research, technology advancement, or development. Each mixed group reviewed all of the rationale statements and group judgments that pertained to work by all five aeronautical R&D institutions within the one work category.

The fifth mixed group dealt with the entire spectrum of work conducted by NASA laboratories. This group considered all rationale and group judgments that applied to work conducted by government laboratories.

Rankings of rationale. The mixed groups first ranked, in order of importance, the rationale statements supporting a particular category of work by each segment of the aeronautical R&D community. The rankings applied only to a single segment and no attempt was made to cross-evaluate rationale for the different types of institutions. The group that considered NASA evaluated the rationale for government laboratories relative to NASA laboratories. The group members ranked the rationale in order of importance within each category of work. There was no attempt made to cross-rank the importance of rationale for different categories of work by NASA.

The rankings for all groups were from 1 (highest) to 5 or 6 (lowest). Statements could also be rated below the numerically ranked items by leaving blanks. A mixed group could indicate that statements were invalid when four out of the five members agreed to it (⊗). The other rankings had to be approved by three or more members of a mixed group. A mixed group could also add new statements of rationale as had been done in the earlier sessions.

Distribution of work. The mixed groups then formulated quantitative judgments of how deeply each segment of the aeronautical R&D community should be engaged in each given category of aeronautical R&D for the Government. Each group arrived at a consensus regarding a reasonable percentage distribution of federal expenditures among the various segments of the aeronautical R&D community for each category of work. These determinations were not meant to represent specific recommended numerical constraints. They were to reflect roughly the expected extent of the relative roles of the various institutions in view of the rationale that had just been considered. The mixed group that considered NASA laboratories indicated their judgments on the percentage distribution of NASA laboratory funds that should be distributed among in-house basic research, applied research, technology advancement, and development. The time allotted for the mixed group sessions was 1 hour and 20 minutes.

INDIVIDUAL EVALUATIONS AND FEEDBACK

A general session was then held for all participants. The author read each mixed group's rankings of rationale. The participants duplicated these rankings onto their copies of the hand-held rationale sheets. This means of feedback probably could have been handled more efficiently by reproducing and distributing these tables. The participants then considered all prior judgments and <u>individually</u> ranked the relative importance of the rationale statements in the left-hand column of their own hand-held rationale sheets (Appendix C, page 193). The author then displayed the mixed group's work distribution. The participants then individually entered their own evaluations of relative work distribution on special tables provided to each individual (Appendix C, page 199). This entry was made for each of the four categories of work and for NASA laboratories. The time allotted for this phase was 1 hour and 25 minutes.

An extremely high dropout rate occurred in filling out individual evaluation forms in the very last portion of this phase, when NASA laboratories were considered. Immediately, 8 participants dropped out and this number steadily increased to 17 dropouts. Only one dropout departed from the conference table. This sudden cessation of activity may have been caused by the laborious nature of information feedback and handwritten individual evaluations. On the other hand, it may also have been caused by concerns that the sponsor (NASA) might be able to trace individual judgments. Such concerns were later expressed to the author by several participants. At the end of the workshop, the participants were instructed to code their written evaluation sheets in a manner that clearly guaranteed anonymity. It would have been better if the coding had been done at the beginning of this session than to postpone it to the end.

SUMMARY OF TRIBUTARY TECHNIQUE

Figure 2 shows a summary of the tributary process. The initial questionnaire was not actually part of the conferencing technique since it was not used in the workshop.

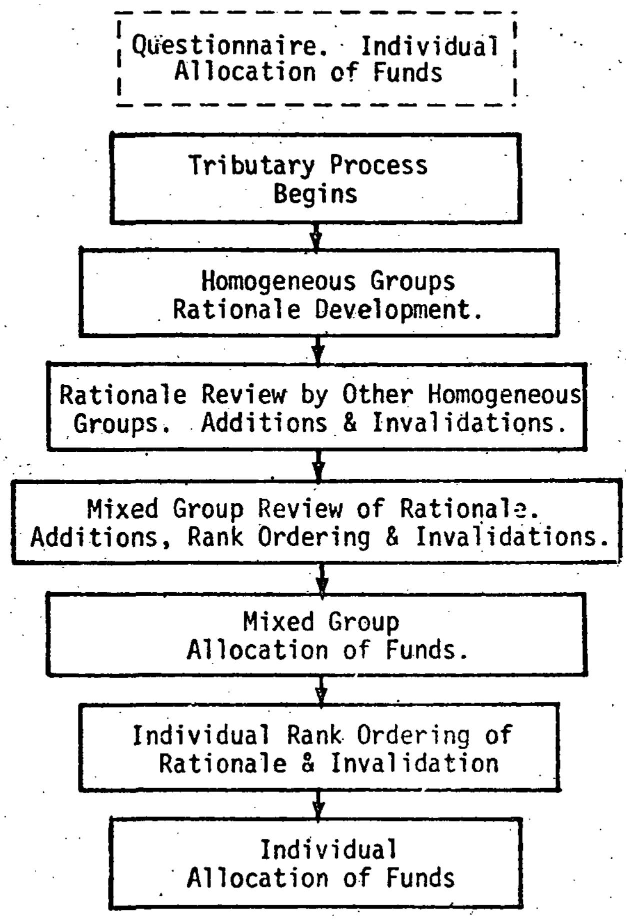

Figure 2: Summary of Tributary Process

TRIBUTARY TECHNIQUE EVALUATION

At the end of the workshop, the participants completed questionnaires aimed at determining their initial reactions to the tributary technique. The results are shown in Appendix C, pages 201-202. Eighty-five percent of the participants stated that this workshop methodology improved communications over their experiences with methodologies used in previous advisory groups where the topics were highly subjective and the advisors had naturally diverse group interests. These participants estimated that they, as a group, had taken part in over 350 categorically similar meetings. The one participant who felt that there was no improvement over prior methods had taken part in about a dozen categorically similar conferences.

QUANTITATIVE METHODS

There were essentially three different types of quantitative data taken during this investigation: *rank order numbers, percentage distributions,* and *opinion ratings.* The first two types of data were averaged for each group and are reported in that form in Chapter 4. The third type is reported without alteration. The average values reported for the rank order data are called *group consensus rankings* or just *consensus rankings.* The average values reported for the percentage distributions are simply called *group percentage distributions.*

It is extremely important to know the probability of chance in regard to the participants' judgments. Variations in agreement among judgments by different members of each group (that is, the scatter in the data) are reflected in statistical probabilities of chance. These probabilities are reported along with all average value data. They indicate the statistical probability that the difference between compared mean values could have occurred by chance. A small value for the probability of chance (P) means that the reported differences between any two or more average values given by a group were probably due to strong agreement among the members of the group rather than just a chance occurrence.

GROUP CONSENSUS RANKINGS

The *group consensus rankings* were calculated by scoring the participants' rankings, averaging the scores, and then re-ranking the items in the same order as the averages.

Rankings and related computations. Appendix C-5 describes the methods used for ranking, re-scoring the rankings, and then calculating the group consensus rankings. Group consensus rankings will be the best estimates of the true overall group rankings if they are statistically significant (71:100-102). In other words, they must reflect a low probability of chance.

In considering rankings, it is important to realize that the judgments do not necessarily correspond to the indicated scale interval. For example, there can be a much greater difference in judgments between items ranked first and second than between the second ranked item and an item ranked third.

Agreement among participants. Measures of the extent of agreement among members of the groups, for the group consensus rankings, were calculated using two related indicators: the *Kendall coefficient of concordance* (W) and the associated probabilities of chance (71:94-106; 72:229-239). The Kendall coefficient of concordance is simply an index. It equals a value of one when there is perfect agreement among the judges and it approaches close to zero when there is no agreement. The Kendall coefficients were corrected for ties awarded to different items in a ranking by the same judge. The correction for ties tends to increase the values of the Kendall coefficients.

The probabilities of chance (P) associated with the Kendall coefficients were also computed for all group consensus rankings (71:94-106; 72:235-237). The probability of chance was not corrected for ties in accordance with accepted methods. It was assumed that the Kendall coefficients and the group consensus rankings were statistically significant when the probabilities of chance were less than or equal to 5 percent ($\alpha < 0.05$). Interesting things occurred when the participants highly agreed on close to the same rank for almost all items, creating mostly ties. The Kendall coefficients went up because of the correction for ties. This index indicated that the members tended to agree. However, the probabilities of chance also increased which correctly indicated that the differences between group consensus rankings for the items became statistically insignificant.

The statistical probability of chance was computed for certain rankings using the χ^2-test (72:175) or the binomial test (72:36-42). These tests were used when there were insufficient variables to employ Kendall coefficients and the related significance tests. In addition, the χ^2-test was used in some important comparisons to evaluate the statistical significance of changes in ranks for a particular item, from one set of circumstances to another. This methodology is covered in greater detail in the discussion of the results. The results presented in Chapter 4 show the probability of chance (P) and the statistical test used in the computations, i.e. W, χ^2, or reference to the binomial distribution.

GROUP PERCENTAGE DISTRIBUTIONS

The questionnaire and workshop called for individual participants to render judgments that involved distributing percentage allocations among a number of items. The percentages were always required to total 100 percent when summed up over all the items in a distribution.

Mean values. The *group percentage distributions* were computed by averaging the percentages allocated to any one item by all members of a group. This averaging was done for each item in the distribution.

Agreement among participants. There were two statistical tests used to determine the extent of agreement between members of a group in regard to the mean values. They were the F-test and the t-test. These statistical tests apply to opinion data which reflect interval scaling in judgments. Both of the tests yield the probabilities that the indicated differences in mean values might have occurred by pure chance. The F-test determines the probability of chance for the indicated differences in group mean values for an entire percentage distribution (73:223-230). The t-test is a method used for small samples to determine if the differences between only two mean values are statistically significant (73:191-198). The probability of chance (P) was computed using the t-test for two related samples (74:386). The statistical probabilities were determined directly from the F distribution and the t distribution using a Texas Instruments SR-52 calculator, a Hewlett-Packard HP-65 calculator, and their associated statistical program packages. The results given in Chapter 4 indicate F and t values and identify which statistical tests were used for comparisons between various mean values.

Chapter 4

RESULTS AND DISCUSSION

The discussion of results is divided into three sections. The first section deals with factors that were hypothesized as distinguishing the various segments of the aeronautical R&D community from each other in regard to conducting work for the Federal Government. These results were obtained by use of the survey questionnaire. The second section of this chapter presents the rationale developed during the workshop by the aeronautical leaders from the various R&D institutions. The third section presents the results on the distribution of work among the various aeronautical R&D institutions for activities ranging from basic research through development.

HYPOTHESIZED DISTINGUISHING FEATURES OF AERONAUTICAL R&D INSTITUTIONS

This section covers the results obtained from the survey questionnaire submitted to the participants prior the the workshop.

QUALITY OF WORK

Table 2 presents the aeronautical leaders' group consensus rankings on the quality of work characteristic of various R&D institutions. The institutions being ranked are shown at the top of the table and the affiliations of the judges are indicated in the left-hand column. Hence, it is possible to read across any row and determine how the aeronautical leaders from each institution ranked the quality of work by all aeronautical R&D institutions. The group consensus rankings are from 1 (highest) to 5 (lowest). Each group consensus ranking was calculated by averaging the ranks given to each institution by all the judges in a group and then awarding *group consensus ranks* to all the institutions in the same order as the averages (pages 62 to 64).

The Kendall concordance coefficient in the right-hand column indicates the degree of agreement among the rankings awarded by the judges affiliated with the group shown in the left-hand column of the table. Perfect agreement would yield a Kendall coefficient of 1 and no agreement would produce a coefficient close to 0 (see page 63). High Kendall coefficients, such as shown in Table 2a, indicate that the individual judges in each group ranked the relative quality of basic research very close to the values shown in the table.

The *total group-consensus rankings* shown in the bottom rows of Table 2 were computed from the individual rankings made by all 25 participants. The total group-consensus ranking is an equally weighted composite of the judgments of the aeronautical leaders from all of the institutions. There was statistically significant agreement, among the total group of leaders, on the rankings of work quality over the full spectrum of R&D. Agreement was assumed to be statistically significant if there was not more than a probability of 5 percent that the indicated comparisons between values could have occurred by chance. In

Table 2

Group Consensus Rankings on Quality of Work

Responses to: ". . . rank the various segments of the aeronautical R and D community in order of the relative overall QUALITY of aeronautical R, T and D work performed. . . . Rank the organizational segments from 1 (highest quality) to 5 (lowest quality) . . . ."

Table 2a: Basic Research

RANKINGS BY↓ / CF→		MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	KENDALL CONCORDANCE COEFFICIENT (W)
MAN COS	(5)	4	5	3	1	2	0.81
SERV COS	(5)	5	3	2	1	4	0.78
NON-PROFS	(5)	5	4	2	1	2	0.74
UNIVS	(5)	5	4	2	1	2	0.85
GOV LABS	(5)	5	4	2	1	2	0.71
ALL 25 PARTICIPANTS		5	4	2	1	2	0.70

Table 2b: Applied Research

RANKINGS OF→ / BY↓	MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	KENDALL CONCORDANCE COEFFICIENT (W)
MAN COS (5)	2	5	3	3	1	* 0.36
SERV COS (5)	4	1	2	5	2	* 0.22
NON-PROFS (5)	4	2	1	5	2	* 0.42
UNIVS (5)	5	4	2	3	1	0.68
GOV LABS (5)	5	3	2	4	1	0.64
ALL 25 PARTICIPANTS	4	3	2	4	1	0.20

Table 2c: Technology Advancement

RANKINGS OF→ / BY↓	MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	KENDALL CONCORDANCE COEFFICIENT (W)
MAN COS (5)	1	3	3	5	2	0.62
SERV COS (5)	2	1	3	5	3	0.51
NON PROFS (5)	5	2	1	4	2	* 0.31
UNIVS (5)	1	2	4	5	3	0.78
GOV LABS (5)	1	3	3	5	1	0.57
ALL 25 PARTICIPANTS	1	2	3	5	3	0.31

Table 2d: Development

RANKINGS OF→ / BY↓	MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	KENDALL CONCORDANCE COEFFICIENT (W)
MAN COS (5)	1	3	3	5	2	0.83
SERV COS (5)	1	2	4	5	3	0.71
NON-PROFS (5)	1	2	2	5	4	0.81
UNIVS (5)	1	2	4	5	3	0.81
GOV LABS (5)	1	2	4	5	2	0.90
ALL 25 PARTICIPANTS	1	2	4	5	3	0.77

Over 95% probability in cases not asterisked that ranking by each group reflected a meaningful group discrimination of differences in ranks, rather than chance variations ($P < \alpha = 0.05$). Asterisk (*) indicates this probability is under 95%.

other words, there had to be at least a probability of 95 percent that the consensus values represented a meaningful overall group discrimination between ranks. The Kendall coefficients indicate that the extent of agreement among all the participants was the highest for basic research and development, which represent the two outer extremes of the R&D spectrum. The extent of agreement among all participants, as a group, was lowest for applied research.

The total group-consensus rankings in Table 2 indicate that the aeronautical R&D institutions produce qualities of work that complement each other across the R&D spectrum. The institutions that characteristically produce the highest quality of work in each category were considered to be universities for basic research, government laboratories for applied research, and manufacturing companies for both technology advancement and development. The total group-consensus rankings for the universities reflect their orientation towards fundamentals, rather than more applied pursuits. The non-profit R&D institutions were recognized as supporting the prime institutions with quality work because they received the second highest places for both basic and applied research. The more applied supporting roles of the service R&D companies were apparent from the second place consensus ranks they received for the quality of technology advancement and development. The quality of work by manufacturing companies was considered high for technology advancement and development, but low for basic and applied research. This finding suggests that manufacturing companies are most oriented towards creating competitive, new, near-term products. They do not seem so well oriented towards research for far-term innovations in aeronautics. The government laboratories were the only institution that received total group-consensus ranks that were within the top three places for the quality of work over the entire spectrum of all R&D activities. This finding implies that government laboratories have a broader orientation than do other aeronautical R&D institutions.

There was significant internal agreement on 75 percent of the sub-group consensus rankings. The aeronautical leaders from the universities and government laboratories were the only two sub-groups that displayed significant internal agreement on all consensus rankings of all four categories of work by all the institutions. There was also remarkably close agreement between these sub-group consensus rankings and the overall consensus rankings by all participants.

Biases in sub-group self-rankings can be evaluated by examining the diagonal of numbers extending from the upper left to the lower right of every table. A bias becomes apparent when a rank on this *self-ranking diagonal* is better than any of the ranks awarded by peer sub-groups. This bias can be seen by comparing a rank on the diagonal with values up and down a column from the diagonal. A total of 45 percent of the sub-group consensus self-rankings was better than any comparable rankings by peer sub-groups. None of the self-rankings were below peer group rankings. It is also interesting to note that three-fourths of the sub-group self-rankings were either 1 or 2 for all categories of work. Every sub-group displayed some natural biases in ranking the quality of their own work, except the university leaders. Hence, there were natural biases when the sub-groups ranked the quality of work by their own institution. However, a careful comparison of sub-group rankings indicates that the total group-consensus ranking, in the bottom rows of Table 2, balanced out individual sub-group biases.

QUALITY OF AERONAUTICAL R&D FROM NASA LABORATORIES

The National Aeronautics and Space Administration (NASA) replaced the National Advisory Committee for Aeronautics (NACA) in 1958. Numerous recommendations have been made that the Government should support all R&D, including aeronautical R&D, in a manner characteristic earlier of NACA (8:53; 23:48; 42:58; 45:Appendix B:9, 11, 19, 29).[1] Table 3a presents the first of several comparisons that were aimed at exploring what basic differences exist, if any, between NACA and NASA laboratories in regard to in-house aeronautical R&D. Table 3a shows the number of aeronautical leaders that ranked the quality of aeronautical R&D by NASA's laboratories either below, equal, or above that of the old NACA.

[1]Notation (8:53; 23:48; 42:58 and so forth means Reference 8: page 53 and Reference 23: page 48 and Reference 42: page 58 and so forth.

All comparisons in Table 3a were statistically significant. The bottom row in this table shows the number of aeronautical leaders that would have been expected to rank NASA respectively below, equal, and above NACA, if the rankings had been made by completely random selections under the probabilities of chance for infinite size samples. When 2 numbers are selected at random and each of them may range from 1 to 5, there are 5 ways that the 2 numbers could turn out equal (P=0.20) and 20 ways that they could be unequal (P=0.80). There is the same probability (P=0.40) that the second number could be higher or lower than the first number. Hence, one would expect that out of every 25 random selections of 2 numbers there would be 5 equal numbers, 10 lower second numbers, and 10 higher second numbers relative to the first numbers selected.

The results in Table 3a indicate that the aeronautical leaders, as a group, believed that the quality of basic research and applied research in aeronautics by NASA laboratories is below that characteristic of the earlier NACA laboratories. The aeronautical leaders, as a group, believed that the quality of NASA's laboratory work in aeronautical technology advancement is about the same as it was for NACA. However, the participants indicated that the quality of NASA's in-house development work in aeronautics is superior to that of NACA.

Table 3b presents a comparison of the quality of aeronautical R&D by NASA laboratories relative to all government laboratories. The results indicate that the aeronautical leaders, as a group, perceived no differences between NASA laboratories and other government laboratories in regard to the quality of any category of work. This conclusion is indicated either by (a) the number of aeronautical leaders that gave equal ranking to both NASA and overall government laboratories, (b) an equal number of leaders ranking NASA both above and below overall government laboratories, and (c) a lack of statistical significance in rankings.

UTILITY OF RESULTS

An initial hypothesis was that the aeronautical R&D leaders would weigh the usefulness of the results produced by the various institutions differently than quality of their work. The results in Table 4

Table 3

Quality of Aeronautical R&D by NASA Laboratories compared with Earlier NACA Laboratories and Overall Government Laboratories (Displays number of leaders making indicated ranking)

Responses to: "Similarly rank the relative QUALITY of in-house aeronautical work characteristic of just NASA/NACA. Use a scale from 1 (highest quality) to 5 (lowest quality) relative to the segments of the aeronautical R and D community shown in the previous matrix. . . . NASA/NACA may rank equal to, higher or lower than the overall government laboratory segment."

Table 3a: NASA (1976) versus NACA (1958)

WORK \ QUALITY FROM →	NASA BELOW NACA	NASA EQUALS NACA	NASA ABOVE NACA	PROBABILITY OF CHANCE χ^2	PROBABILITY OF CHANCE PROB. (P)
BASIC RESEARCH	17	6	2	11.50	0.3%
APPLIED RESEARCH	14	7	4	6.00	5.0%
TECHNOLOGY ADVANCEMENT	5	12	8	12.70	0.2%
PRODUCT DEVELOPMENT	3	7	15	8.20	1.7%
EXPECTED FROM PURE CHANCE	10	5	10		

Table 3b: NASA versus Overall Government Laboratories

WORK \ QUALITY FROM →	NASA BELOW GOV LABS	NASA EQUALS GOV LABS	NASA ABOVE GOV LABS	PROBABILITY OF CHANCE χ^2	PROBABILITY OF CHANCE PROB. (P)
BASIC RESEARCH	8	9	8	4.00	* 13.6%
APPLIED RESEARCH	9	12	4	13.50	0.1%
TECHNOLOGY ADVANCEMENT	5	11	9	9.80	0.7%
PRODUCT DEVELOPMENT	11	7	7	1.80	* 40.7%
EXPECTED FROM PURE CHANCE	10	5	10		

Table 4

Comparisons of Rankings of Work Quality versus Utility of Results
(Shown in number of leaders making rankings)

Responses to: ". . . rank the various segments of the aeronautical R and D community in order of the relative overall USEFULNESS of the RESULTS they produced. . . . Rank the results produced by each organization in order of USEFULNESS from 1 (greatest usefulness) to 5 (least usefulness) . . . ."

WORK CATEGORY	CONDUCTED BY	UTILITY BELOW QUALITY	UTILITY EQUALS QUALITY	UTILITY ABOVE QUALITY	PROBABILITY OF CHANCE	
					X^2	PROB. (P)
BASIC RESEARCH	MAN COS	1	19	5	49.80	Below 0.1%
	SERV COS	2	17	6	36.80	"
	NON-PROFS	4	21	0	64.80	"
	UNIVS	4	21	0	64.80	"
	GOV LABS	7	17	1	37.80	"
APPLIED RESEARCH	MAN COS	5	14	6	20.30	"
	SERV COS	5	16	4	30.30	"
	NON-PROFS	4	16	5	30.30	"
	UNIVS	9	11	5	9.80	"
	GOV LABS	4	17	4	36.00	"
EXPECTED FROM PURE CHANCE		10	5	10		

Table 4 (Continued)

WORK CATEGORY	CONDUCTED BY	UTILITY BELOW QUALITY	UTILITY EQUALS QUALITY	UTILITY ABOVE QUALITY	PROBABILITY OF CHANCE	
					X^2	PROB. (P)
TECHNOLOGY ADVANCEMENT	MAN COS	5	13	7	16.20	Below 0.1%
	SERV COS	7	15	3	25.80	"
	NON-PROFS	6	17	2	36.80	"
	UNIVS	4	18	3	42.30	"
	GOV LABS	3	15	7	25.80	"
PRODUCT DEVELOPMENT	MAN COS	0	25	0	100.00	"
	SERV COS	4	18	3	42.30	"
	NON-PROFS	3	19	3	49.00	"
	UNIVS	2	22	1	72.30	"
	GOV LABS	3	17	5	36.20	"
EXPECTED FROM PURE CHANCE		10	5	10		

indicate that the participants did not differentiate between utility and quality. Hence, no further comparisons for the utility of R&D are presented in this publication.

ABILITY TO FOCUS ON SPECIFIC REAL PROBLEMS

Table 5 presents group consensus rankings on the characteristic ability of the aeronautical R&D institutions to focus on achieving solutions to specific real problems.

Table 5

Ability to Focus on Solving Specific Real Problems
Group Consensus Rankings

Responses to: "All other things being equal, rank each of the following types of organization in order of their ability to focus on achieving solutions to specific real problems. . . . from 1 (most able) to 5 (least able) for each type of organization."

RANKINGS BY↓ / OF→		MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	KENDALL CONCORDANCE COEFFICIENT (W)
MAN COS	(5)	1	3	2	5	4	0.52
SERV COS	(5)	1	2	3	5	3	* 0.34
NON-PROFS	(5)	1	2	3	5	4	0.65
UNIVS	(5)	1	1	3	5	3	0.65
GOV LABS	(5)	1	2	3	5	3	0.54
ALL 25 PARTICIPANTS		1	2	3	5	4	0.42

Over 95% probability in cases not asterisked that ranking by each group reflected a meaningful group discrimination of differences in ranks, rather than chance variations ($P < \alpha = 0.05$). Asterisk (*) indicates this probability is under 95%.

There was significant agreement on the total group-consensus ranking shown on the bottom of the table. The total group-consensus ranking indicates that manufacturing companies were believed to have the greatest ability to focus on solving specific real problems. The manufacturing companies were followed in order of ability by service R&D companies, non-profit R&D institutions, government laboratories, and universities. It is interesting to note that the government laboratories were ranked fourth in this comparison even though they were ranked first on the quality of applied research shown in Table 2b on page 67. This infers that the government laboratories were considered to produce the highest quality applied research, but they did not seem so effective in bringing their talents and resources to bear on solving specific real problems as are most institutions in the private sector.

The sub-group consensus rankings were not markedly different than the total group-consensus ranking. Only the sub-group from service R&D companies, internally, did not significantly agree on their consensus rankings. The government laboratories were ranked between third and fourth by all sub-groups. Even the leaders from the universities ranked their institution last in regard to the ability to focus on and solve specific real problems.

DISSEMINATION OF RESEARCH AND TECHNOLOGY

There are two types of results that occur when the Government expends funds on research and technology. The primary results appear at the end of the effort in terms of a required output, such as a document, a computer program, or hardware. The primary output often enters the public domain under most government contracting procedures for research and technology. However, there is also a secondary result in the form of an increased capability and retained body of knowledge that remains within the organization that performed the work. This increment in internal capability and captured knowledge can give performing organizations a competitive advantage over other organizations. The Government may indeed wish to build up residual capabilities and stores of knowledge in aeronautical R&D organizations. However, the Government may also wish to have this publically funded knowledge and capacity openly accessible for purposes that will serve all American aviation. The staff of the Senate Committee on Aeronautics and Space Sciences expressed the following concern in regard to aeronautical research:

> We question whether scientists and engineers in private industry who are exploring new basic technology under contract to NASA are truly accessible to engineers in competing companies . . . . Thus, we are concerned that heavy reliance on out-of-house contracting for basic aeronautical research will inhibit healthy competition in the industry's application of that technology (53:23).

Table 6 presents group consensus rankings on the willingness of the various institutions to provide outside organizations with full information on government-funded research and technology, even beyond the information contained in published reports required by the Government. Development purposely was not considered in this assessment because competition in even government-funded development programs is considered desirable in the free enterprise economic system. Competition naturally leads to restrictions in disclosures between competitors. However, the Government usually expends funds on aeronautical research and technology advancement specifically for the purpose of advancing the overall aviation industry.

There was remarkably high agreement among the total group of 25 aeronautical leaders in regard to the relative willingness of different types of institutions to fully disclose the results of government-funded research and technology. The total group-consensus rankings indicate the following things. The universities were considered the most willing to provide full information. They were followed in descending order of willingness by government laboratories, non-profit R&D institutions, service R&D companies, and finally, manufacturing companies (Table 6). It is interesting that this was the exact reverse of the total group-consensus rankings of the characteristic ability of these institutions to focus on and solve specific real problems (Table 5). The results in Tables 5 and 6 thus imply that the greatest competitive inclinations tend to exist on the part of institutions whose internal capabilities are most directly oriented toward solving problems associated with specific applications.

The results shown in Table 6 are consistent with earlier investigations. Vollmer found that research managers sampled in industry indicated that it would be cause for dismissal if a researcher gave research ideas to outsiders without clearance from his own management (57:61). However, research managers sampled in universities, government laboratories, and non-profit R&D institutions indicated that giving research ideas to outsiders would not be adequate grounds for dismissal in those institutions. The evidence obtained on publication rates and the influence of publications on salaries of engineers and scientists in these institutions all indicated that open publication was more frequent and was valued to a greater extent in universities, government laboratories, and non-profit institutions, than they were in manufacturing companies.

It is interesting to note in Table 6 that even the leaders from the manufacturing companies ranked their own institution last. The leaders from the service R&D companies ranked their own institution next to last. There was strong internal agreement in these sub-groups on these rankings. The sub-group consensus rankings were also close to the total group-consensus rankings by all participants.

Table 6

Willingness to Disseminate Research and Technology
Group Consensus Rankings

Responses to: "Rank the following types of organization in order of their willingness to provide outside organizations with FULL INFORMATION on government funded RESEARCH and TECHNOLOGY, even beyond the information contained in published reports required by the government. . . . write one number in each box, from 1 (most willing) to 5 (least willing) for each segment of the aeronautical community."

RANKINGS BY↓ / OF→	MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	KENDALL CONCORDANCE COEFFICIENT (W)
MAN COS (5)	5	4	3	1	2	0.80
SERV COS (5)	5	4	3	1	1	0.58
NON-PROFS (5)	5	4	2	1	2	0.90
UNIVS (5)	5	4	3	1	2	0.89
GOV LABS (5)	5	4	3	1	1	0.95
ALL 25 PARTICIPANTS	5	4	3	1	2	0.79

Over 95% probability in all cases that ranking by each group reflected a meaningful group discrimination of differences in ranks, rather than chance variations.

EXPERIMENTAL FACILITIES

Figure 3 indicates that the aeronautical leaders from all R&D institutions quite strongly believed that major aeronautical experimental facilities built by the Federal Government should be managed by organizations that would provide usage and/or results to the entire aeronautical community.

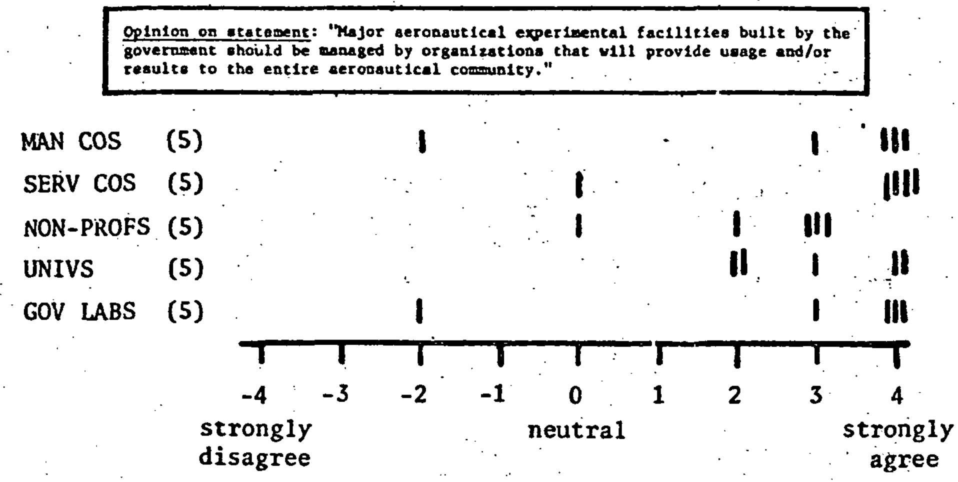

Figure 3: Usage of Major Experimental Facilities and Results

Figure 4 shows the aeronautical leaders from all R&D institutions were substantially of the opinion that resident research groups should be located at major experimental facilities, if these facilities can be useful for basic or applied research.

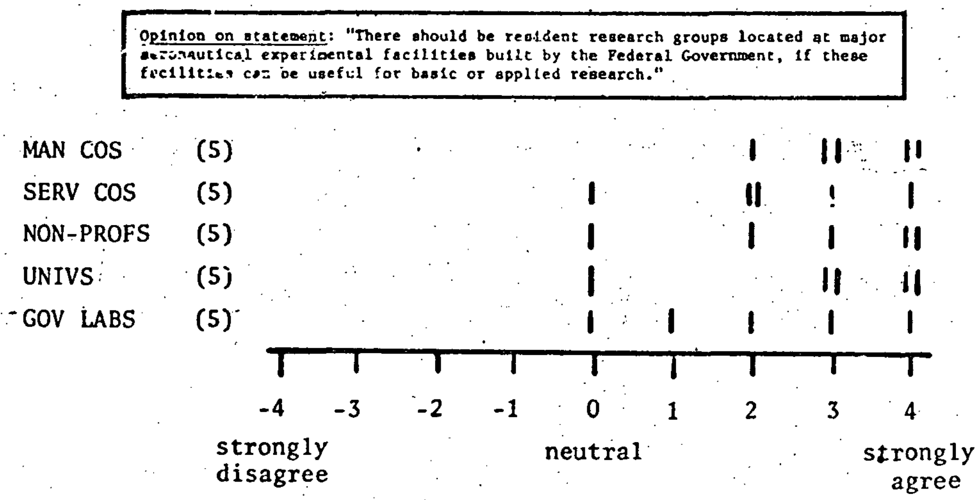

Figure 4: Location of Research Groups at Major Experimental Facilities

Figure 5 indicates the aeronautical leaders' views on whether government or private institutions can most effectively manage and control major experimental facilities for aeronautical R&D. The subgroups from the manufacturing companies and service R&D companies were almost evenly divided on this issue. The leaders from non-profit R&D institutions believed that institutions in the private sector could most effectively manage and control these facilities. The leaders from government laboratories and universities both believed the Government could most effectively manage and control major government-built experimental facilities.

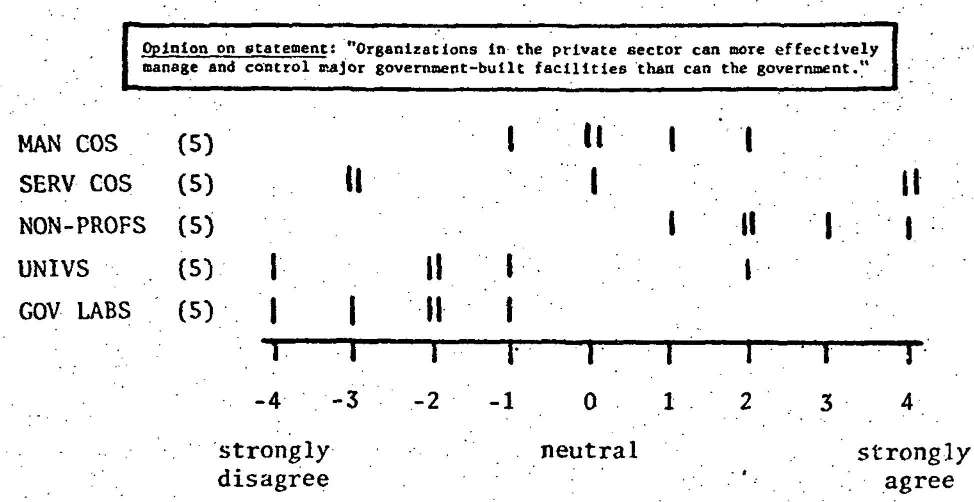

Figure 5: Most Effective Institutional Control of Major Government-Built Experimental Facilities

Table 7 presents the aeronautical leaders' final judgments on the organizations that actually should have custody and managerial control of major aeronautical experimental facilities built by the Federal Government. The institutional affiliation of each group of judges is shown in the first column at the left of the table. The top row of the table displays the types of organizations that would receive a percentage of the total capital value of the major experimental facilities built by the Federal Government. The figures in the columns under each type of institution show the average percentages of the total capital value of all such facilities that were awarded to that organization by each of the sub-groups shown in the column on the far left of the table. The values in each row should total 100 percent except for small round off errors. The distribution of average percentages among the various institutions, along each row, is termed the *group percentage distribution* of experimental facilities. The column of numbers on the far right of Table 7 gives the probability that the group percentage distribution in each row might have occurred by chance.

Table 7

Distribution of Major Experimental Facilities
Group Consensus Percentage Distribution

(percentage of total capital value of all major, government-built, aeronautical, experimental facilities--over $1,000,000 each)

Responses to: "Roughly indicate the percentage of the capital value of all major aeronautical experimental facilities built by the government that you think should be located at and under the managerial control of the following types of organizations."

DISTRIBUTION FOR → BY↓		MAN COS	SERV COS	NON-PROFS	UNIVS	GOV LABS	GOV TEST ORG	PROBABILITY OF CHANCE F	PROBABILITY OF CHANCE PROB. (P)
MAN COS	(5)	3 %	6 %	3 %	8 %	47 %	33 %	9.50	P<0.1%
SERV COS	(5)	0	20	6	9	26	39	2.90	3 %
NON-PROFS	(4)	12	15	12	9	28	24	* 1.63	20 %
UNIVS	(5)	7	5	12	10	38	28	8.38	P<0.1%
GOV LABS	(5)	3	2	10	7	57	21	7.05	P<0.1%
ALL RESPONSES	(24)	5 %	10 %	8 %	8 %	40 %	29 %	23.57	P<0.1%

There was significant agreement among all participants on the total group percentage distribution shown on the bottom row of Table 7. The total group decision favored placing the largest share of the experimental facilities under the Government (69%). This could be a reflection of aeronautical leaders' concern over general accessability by their organizations to the facilities and the results from these facilities. The aeronautical leaders distributed more of the major experimental facilities to government laboratories (40%) than to government test centers (29%). This result reflected their interest in having resident research groups at these facilities.

There was significant internal agreement in all the sub-groups on the percentage distribution of experimental facilities, except for the sub-group from the non-profit R&D institutions. Non-profit R&D institutions was the only sub-group that also believed that the private sector could more effectively manage and control major experimental facilities built by the Government (Figure 5). The various sub-groups differed by factors of two or more in regard to some of the percentages of experimental facilities allocated to certain institutions. The differences are easily reconciled by taking self-oriented biases into account and neglecting the statistically non-significant results. In fact, the group consensus distribution for the total group apparently balanced out most of the biases.

TECHNICAL GUIDANCE ON CONTRACTS

The policy of the Office of Management and Budget (OMB) has been to contract as much government work as possible to the private sector rather than having it done by the Government itself (54). Assume for a moment that all aeronautical R&D was contracted to the private sector without regard to any other factor. First of all, the Government would still have to select and plan paths to advance aeronautical R&D. It would still have to determine the best technical programs to pursue. These decisions involve resolving technical issues regarding both what is needed and what is feasible. The Government would still have to select the best technical projects from among many proposals. It would have to continue to seek contractors, evaluate the technical merits of competitive proposals, select the best proposals and most competent contractors for the work, provide the contractors with technical guidance toward the desired goals, insure that the technical progress of the work remained on track, provide additional

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Technology advancement (T) is the systematic adaptation and use of knowledge to achieve the capability of practical industrial applications, the expansion of the engineering and industrial arts, and advancement of the mechanisms for product development and production. This includes expansion of basic engineering data, methods, techniques, basic componentry, tools, and experience needed to be able to develop and produce products. This process sometimes requires major large-scale hardware integration steps, including building and testing "bread boards" of components, "technology demonstration" hardware, and so-called "proof-of-concept" hardware. Technology advancement can be properly and successfully justified on the basis of being necessary preparatory steps to achieve needed, or improved, product developments or manufacturing methods.

Development (D) is the study, design, engineering, testing, tooling, and construction that are necessary prior to, and for the purpose of, obtaining an end product to be manufactured. It includes the development of end-item components and subsystems. The development process results in one or more prototype test articles from which evolves the item to be manufactured.

APPENDIX C

APPENDIX C-1

QUESTIONNAIRE

School of Business and Management
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Palo Alto, California 94304

AERONAUTICS ADVISORY SURVEY
FEDERALLY SUPPORTED AERONAUTICAL R, T and D

I. INTRODUCTION

In this questionnaire we request some fairly general judgments, advice and opinions regarding the conduct of federally supported aeronautical R, T and D by the various segments of the aeronautical R and D community. For the purpose of this questionnaire, Federal support of the private sector will mean all government expenditures, direct and indirect, associated with contracts and grants to the private sector for original R, T and D. These funds may come from any Federal source, including government laboratories. On the other hand, Federal support of and related expenditures by government laboratories will refer to all government funds, direct and indirect, for ORIGINAL IN-HOUSE R, T and D conducted by government engineers and scientists from these laboratories. This includes all Federal funds expended for salaries, overhead, facility constructions, instrumentation and all support service contracts associated with government laboratory personnel conducting in-house work.

II GENERAL INSTRUCTIONS

The questions that follow will require considerable thought based on your general background and experience. At times, you may feel that your background is insufficient to give firm answers. Nevertheless, we would appreciate it if you would fully answer all of the questions as best you can. We expect to gain considerable insight from the sum total of all the responses because the cumulative experience of all the participants will be quite broad. The relative degree of uncertainty the participants may have in regard to any questions will be properly reflected by the scatter of the data, that is the variation in the answers received from all participants as a group. Therefore, it is important that you completely answer all questions.

Some questions ask you to make a single selection from among a group of answers, where more than one may seem to apply. Please select the answer that seems most applicable, but never give more than the number of answers requested.

III. BACKGROUND AND EXPERIENCE

PROFESSIONAL BACKGROUND

1. Highest Degree (check one)
   - ☐ Bachelors Degree
   - ☐ Masters Degree
   - ☐ Engineers Degree
   - ☐ PhD
   - ☐ Other______ (write in)

2. Primary Discipline (check one)
   - ☐ Aeronautical Engineer
   - ☐ Chemical Engineer
   - ☐ Chemistry
   - ☐ Civil Engineer
   - ☐ Mathematics
   - ☐ Mechanical Engineer
   - ☐ Metallurgy
   - ☐ Meteorology
   - ☐ Physics
   - ☐ Other______ (write in)

3. Years Technical Experience (circle one number from 1 to 7)

1	2	3	4	5	6	7
0-5	6-10	11-15	16-20	21-25	26-30	over 31 years

4. Circle the number closest to the percentage of work for which you are responsible that is directly supported by the government

0 — 10 — 20 — 30 — 40 — 50 — 60 — 70 — 80 — 90 — 100%

JOB DESCRIPTION

5. ☐ General Management: Corporate officials, owners, directors, general managers and military equivalents.
   - ☐ Technical Management: V.P. Eng., Tech. Dir., Proj. Eng., Proj.Man.
   - ☐ Engineering: Engineer, designer, test engineer, development engineer, etc.
   - ☐ Scientist: Scientist or research engineer.
   - ☐ Production
   - ☐ Air Operations: Pilots, maintenance, aircraft, sales, etc.
   - ☐ Administrative: Staff, procurement, legal, etc.
   - Other:______ (write in)

PRIMARY AREAS OF CONCERN

6. VEHICLES (check one)
   - ☐ Military aircraft of all types
   - ☐ Military missiles (atmospheric flight)
   - ☐ Civil air transporation and related aircraft
   - ☐ General aviation and related aircraft
   - ☐ Aeronautics in general
   - ☐ Other:______ (write in)

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7. TECHNICAL DISCIPLINE (Check below only one prime topic area, i.e. check one box)

Systems technology
- ☐ Vehicle design, studies and analyses
- ☐ Effectiveness and safety
- ☐ Support Systems
- ☐ Flight Testing

Atmospheric sciences
- Aero acoustics
- ☐ Atmospheric environment
- ☐ Fluid and gas dynamics
- ☐ Thermophysics
- ☐ Plasmadynamics

Propulsion
- Air breathing prop. systems

Propulsion, continued
- ☐ Rocket propulsion systems
- ☐ Fuels and propellants
- ☐ Combustion

Mechanics and Control
- ☐ Flight mechanics and Control
- ☐ Guidance and control
- ☐ Avionics

Structures and Materials
- ☐ Structures
- ☐ Structural dynamics
- ☐ Materials
- ☐ Other ____________ (write in)

DEFINITIONS OF CATEGORIES OF R, T and D WORK

Read over all the following definitions of categories of aeronautical R&D work. These definitions will be used throughout the questionnaire; therefore, it is very important for you to be completely familiar with them. You will also need them to answer the next questions about yourself.

BASIC RESEARCH (R) - is the SCIENTIFIC pursuit of fundamental KNOWLEDGE in a general technical area, independent of known applications. The results consist of new theories, basic experimental observations (data), and understanding of physical nature. The knowledge gained is expected to be of such interest or value within the technical area, that the work can be properly and successfully justified without being tied to specific known applications.

APPLIED RESEARCH (R) - is also the SCIENTIFIC pursuit of fundamental KNOWLEDGE, but it is aimed toward restricted types of applications or a particular application. The results consist of theories, systematic experimental data (which may be quite extensive and detailed) and understanding. Applied research solves the basic problems and opens the way for the technological advancements needed to achieve the desired applications. Applied research is properly and successfully justified primarily by expected advances relative to such applications.

TECHNOLOGY ADVANCEMENT (T) - is the systematic adaptation and use of knowledge to achieve the capability of practical industrial applications, the expansion of the ENGINEERING and INDUSTRIAL ARTS, and advancement of the MECHANISMS for product development and production. This includes expansion of basic engineering data, methods, techniques, basic componentry, tools and experience needed to be able to develop and produce products. This process sometimes requires major large-scale hardware integration steps, including building and testing "bread boards" of components, "technology demonstration" hardware and so-called "proof-of-concept" hardware. Technology advancement can be properly and successfully justified on the basis of being necessary preparatory

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steps to achieve needed, or improved, product developments or manufacturing methods.

DEVELOPMENT (D) - the study, design, engineering, testing, tooling, and construction that are necessary prior to, and for the purpose of, obtaining an end product to be manufactured. It includes the development of end-item components and subsystems. The development process results in one or more prototype test articles from which evolves the item to be manufactured.

YOUR CATEGORY OF WORK

8. Refer to the preceding definitions of R, T and D. Check the kind of aeronautical work below that you are primarily associated with in your current position (check one).

- ☐ Basic Research
- ☐ Applied Research
- ☐ Technology Advancement
- ☐ Development
- ☐ Other ________ (Write in)

9. Refer again to the preceding list of definitions of R, T and D. Check the type of work below that is the primary business of your company, division, or organization (check one).

- ☐ Basic Research
- ☐ Applied Research
- ☐ Technology Advancement
- ☐ Development
- ☐ Other ________ (Write in)

DEFINITIONS
OF
SEGMENTS OF THE AERONAUTICAL R&D COMMUNITY

Read over all of the following definitions of organizations involved in aeronautical R, T and D. These definitions of the various segments of the aeronautical R and D community are used throughout the questionnaire. It is important to be familiar with all of the definitions. Questions about them will follow.

MANUFACTURING COMPANIES (MAN COS) - commercial concerns that primarily manufacture products as their major source of gross income and profits.

SERVICE R&D COMPANIES (SERV COS) - commercial concerns that principally provide original R, T or D and other non-manufacturing services for other companies, government agencies or the public to obtain its primary source of gross income and profits. Service may extend from research to product development, such as may be performed by research associations, consulting firms and small R&D companies.

NON-PROFIT R&D INSTITUTIONS (NON-PROFS) - institutes and institutions that primarily perform R, T and D services for companies, the government or the public--without opportunity for profit, dividends or capital gains by owners. This segment includes separate institutes affiliated with universities and non-profit subsidiaries of profit companies.

UNIVERSITIES (UNIVS) - colleges, technical institutes, technical schools or universities where education is recognized as the central function of the organization, and within which other professional activities in R, T and D exist to a greater or lesser extent than education.

GOVERNMENT LABORATORIES (GOV LABS) - all in-house government laboratories where original aeronautical R, T or D is performed. Such laboratories may also contract with organizations in the private sector for R, T and D to a greater or lesser extent than the in-house work. For the purpose of this survey, work by government laboratories refers strictly to in-house work and direct expenditures by government laboratories related to in-house work.

GOVERNMENT R&D FUNDING ORGANIZATIONS (GOV FUND ORGS) - government organizations that distribute technical work among other groups, monitor the work and provide funding for contract or in-house government R, T or D done by other organizations. Government R&D funding organizations do little or no in-house R, T or D of their own in comparison to their funding activities. But, they may be involved in considerable technical monitoring, study, direction, and guidance activities.

YOUR AFFILIATION

10. Referring to the previous list of organizational definitions, check the type of organization below that best describes the principal nature of your company, division, institution or government organization.

- ☐ Manufacturing Company
- ☐ Service R&D Company
- ☐ Non-profit R&D Company
- ☐ Government Lab
- ☐ Government R&D Fund Org
- ☐ Other __________ (Write in)

IV. JUDGMENTS, OPINIONS AND ADVICE

11. QUALITY OF WORK

In the following matrix, rank the various segments of the aeronautical R&D community in order of the relative overall QUALITY of aeronautical R, T and D work performed. Proceed down each column in the matrix and enter one number in each box. Rank the organizational segments from 1 (highest quality) to 5 (lowest quality) for the type of work indicated at the head of the column. See definitions given on pages 3-5.

QUALITY OF WORK

	Basic Research	Applied Research	Technology Advancement	Development
MAN COS				
SERV COS				
NON-PROFS				
UNIVS				
GOV LABS				

Sample
1
4
5
3
2

12. Similarly rank the relative QUALITY of in-house aeronautical work characteristic of just NASA/NACA. Use a scale from 1 (highest quality) to 5 (lowest quality) relative to the segments of the aeronautical R&D community shown in the previous matrix. NASA/NACA laboratories fall within the general category of government laboratories. Nevertheless, NASA/NACA may rank equal to, higher or lower than the overall government laboratory segment.

QUALITY OF WORK BY NASA/NACA

	Basic Research	Applied Research	Technology Advancement	Development
NASA				
NACA (to 1958)				

13. USEFULNESS OF RESULTS

In the following matrix, rank the various segments of the aeronautical R&D community in order of the relative overall USEFULNESS of the RESULTS they produced. Proceed down each column in the matrix and enter one number in each box. Rank the results produced by each organization in order of USEFULNESS from 1 (greatest usefulness) to 5 (least usefulness) for the type of work shown at the head of each column.

USEFULNESS OF RESULTS

	Basic Research	Applied Research	Technology Advancement	Development	Sample
MAN COS					2
SERV COS					3
NON-PROFS					1
UNIVS					4
GOV LABS					5

14. Similarly rank the relative overall USEFULNESS of the in-house aeronautical work characteristic of just NASA/NACA. Again, use a scale from 1 (greatest usefulness) to 5 (least usefulness) relative to the segments of the aeronautical community shown in the previous matrix.

USEFULNESS OF NASA/NACA RESULTS

	Basic Research	Applied Research	Technology Advancement	Development
NASA				
NACA (to 1958)				

15. PROBLEM CONSTRAINTS

All other things being equal, rank each of the following types of organization in order of their ability to focus on achieving solutions to specific real problems. Proceed down the column and write one number in each box, from 1 (most able) to 5 (least able) for each type of organization.

	Ability to Focus
MAN COS	
SERV COS	
NON-PROFS	
UNIVS	
GOV LABS	

16. DISSEMINATION OF RESEARCH AND TECHNOLOGY

Rank the following types of organization in order of their willingness to provide outside organizations with FULL INFORMATION on government funded RESEARCH and TECHNOLOGY, even beyond the information contained in published reports required by the government. Proceed down the column and write one number in each box, from 1 (most willing) to 5 (least willing) for each segment of the aeronautical community.

	Willingness to provide information
MAN COS	
SERV COS	
NON-PROFS	
UNIVS	
GOV LABS	

MAJOR EXPERIMENTAL FACILITIES

A major experimental facility is defined here as a general experimental facility costing about a million dollars or more. Please indicate your opinion in regard to the following statements by circling an appropriate number following each statement.

17. "Major aeronautical experimental facilities built by the government should be managed by organizations that will provide usage and/or results to the entire aeronautical community."

4 -3 -2 -1 0 1 2 3 4

strongly disagree — neutral — strongly agree

18. "Organizations in the private sector can more effectively manage and control major government-built facilities than can the government."

4 -3 -2 -1 0 1 2 3 4

strongly disagree — neutral — strongly agree

19. "There should be resident research groups located at major aeronautical experimental facilities built by the Federal Government, if these facilities can be useful for basic or applied research."

4 -3 -2 -1 0 1 2 3 4

strongly disagree — neutral — strongly agree

20. Roughly indicate the percentage of the capital value of all major aeronautical experimental facilities built by the government that you think should be located at and under the managerial control of the following types of organizations.

Manufacturing Cos:	____%
Service R&D Cos:	____%
Non-Profit Institutions	____%
Universities:	____%
Government Labs:	____%
Government Test Centers:	____%
Total:	100%

21. TECHNICAL GUIDANCE OF CONTRACTS

In the following matrix, rank the various segments of the aeronautical R&D community in order of how well you believe they can provide the government with IMPARTIAL TECHNICAL GUIDANCE on CONTRACTS with other organizations for each of the indicated categories of work. Contract technical guidance includes: technical advocacy of needed new contracts, technical evaluation of proposals, selection of competent contracts, technical guidance of contractors, checking technical work, helping solve technical problems and evaluating results. Proceed down each column and enter one number in each box. Rank each type of organization in order of ability to provide government with impartial technical contract guidance by entering a number from 1 (most able) to 6 (least able) for each of the categories of work shown at the head of the column. See pages 3-5 for definitions of any terms that are unfamiliar.

IMPARTIAL TECHNICAL GUIDANCE ON CONTRACTS

	Basic Research	Applied Research	Technology Advancement	Development
MAN COS				
SERV COS				
NON-PROFS				
UNIVS				
GOV LABS				
GOV FUND ORG				

22. DISTRIBUTION OF WORK

This question is intended to reflect your view on roughly the extent to which different segments of the aeronautical R&D community should participate in each category of federally funded work in order to best advance American aeronautics. Assume that there is a set amount of federal funding available for each category of work. Write the percentage of these funds that you feel should be expended by each segment of the aeronautical R&D community.

The introduction (Page 1) defines the funding break-down relative to government laboratories and their contractors. You might refer back to it if this is not clear now. It might also be a good idea at this point to review the definitions of the work categories on pages 3-4.

DISTRIBUTION OF WORK IN EACH AREA
(Percent-%)

	Basic Research	Applied Research	Technology Advancement	*Development*	*(Sample)*
MAN COS					10
SERV COS					25
NON-PROFS					15
UNIVS					40
GOV LABS					10
TOTAL	100%	100%	100%	100%	100%

23. This question asks how NASA/NACA, from what you know of them, appears to have apportioned in-house expenditure for the various categories of aeronautical work.

Proceed down each of the first two columns in the matrix below. Indicate the percentage of NASA/NACA expenditures for in-house aeronautical efforts that you think probably related to each category of work. It might be worthwhile to again review the definitions of work on Pages 3-4.

RELATIVE EMPHASIS IN NASA/NACA CENTERS

	Apparent Distribution Expenditures		Recommended Distribution Of NASA's work
	NACA (to 1958)	NASA	
Basic Research			
Applied Research			
Technology			
Development			
TOTAL	100%	100%	100%

Next, go to the third column in the preceding matrix. For each category of work, write in the percent of NASA's in-house expenditures for aeronautics that you think would probably result in the greatest contribution to American aeronautics.

APPENDIX C-2

AGENDA

Thursday, 5 August 1976

MORNING SESSIONS

8:00 - 8:25 INTRODUCTORY SESSION

Location: Regency Room, Rickey's Hyatt House, see enclosed map. (Coffee and rolls will be available in the room starting at 7:30 a.m.)

Opening Comments:	H. Harvey Album Chairman	5 minutes
	Stewart Fliege Pepperdine University	5 minutes
	J. Lloyd Jones NASA Ames Research Center	20 minutes

8:25 - 8:45 WORKSHOP METHODOLOGY AND DEFINITIONS OF TERMS

- Definitions of organizational segments
- Definitions of work categories
- Procedures
- Role of Observers

The morning session is devoted to establishing a consensus of views on the following questions:

a. Which segments of the aeronautical R&D community should conduct federally supported work in (1) basic research, (2) applied research, (3) technology advancement, and (4) development?

b. What are the commonly recognized and agreed upon reasons why such work should be conducted by particular segments of the aeronautical R&D community?

8:50 - 9:50 HOMOGENEOUS GROUPS

The participants will be divided into five groups. Each group will consist of representatives of a single segment of the aeronautical R&D community. The groups will meet in separate rooms as follows:

Manufacturing Companies	Rm. A	Universities	Rm. D
Service R&D Companies	Rm. B	Government Labs	Rm. E
Non-profit Institutions	Rm. C		

9:55 - 10:20	REVIEW AND EXPANSION OF RATIONALE				

The groups will go through a rotation process by which they will review and expand upon each other's logic. Room assignments:

Manufacturing Companies	Rm. B	Universities	Rm. E
Service R&D Companies	Rm. C	Government Labs	Rm. A
Non-profit Institutions	Rm. D		

10:20 - 10:35 BREAK

10:35 - 11:00 Room Assignments:

Manufacturing Companies	Rm. C	Universities	Rm. A
Service R&D Companies	Rm. D	Government Labs	Rm. B
Non-profit Institutions	Rm. E		

11:05 - 11:30 Room Assignments:

Manufacturing Companies	Rm. D	Universities	Rm. B
Service R&D Companies	Rm. E	Government Labs	Rm. C
Non-profit Institutions	Rm. A		

11:35 - noon Room Assignments:

Manufacturing Companies	Rm. E	Universities	Rm. C
Service R&D Companies	Rm. A	Government Labs	Rm. D
Non-profit Institutions	Rm. B		

noon - 1:00 LUNCH

AFTERNOON SESSIONS

1:30 - 1:50 GENERAL SESSION, Regency Room

- Review of morning results
- Explanation of objectives and methodology for afternoon

The afternoon session is aimed at establishing a consensus of views, if possible, on the following questions:

a. What is the relative importance of the agreed-upon reasons for various segments of the aeronautical R&D community conducting given categories of government funded work?

b. Roughly, what should be the percentage distribution of federally supported work (federal funding) among the various segments of the aeronautical community for each category of work?

2:00 - 3:20 MIXED GROUPS

The participants will again be divided into five groups; however, this time each group will consist of one representative from each of the five segments of the aeronautical R&D community. Each of these groups will meet in a separate room where the participants will concentrate on a particular category of work. However, one group will be concerned specifically with in-house work by NASA Laboratories.

Room assignments:

Basic Research	Rm. A	Development	Rm. D
Applied Research	Rm. B	NASA	Rm. E
Technology Advancement	Rm. C		

3:20 - 3:35 BREAK

3:35 - 5:00 GENERAL SESSION, Regency Room

- Reports on results of mixed group sessions
- Registering individual views (written)

5:00 - 5:20 FEDERAL FUNDING FOR AERONAUTICS - GENERAL DISCUSSION

- Review disposition of federal funding (J. R. Chirichiello)
- Concluding remarks (H. H. Album)

APPENDIX C-3

EXAMPLE OF FLIP CHART

do not write in this column	*TECHNOLOGY ADVANCEMENT/UNIVS*
	A. The training of students for the later practice of engineering is furthered by university activity in technology advancement. *B. Experience has shown in some cases, that the Government can obtain outstanding technology advancement from universities.* *C. The effort in universities to achieve large jumps in technology can serendipitously stimulate the development of fundamental fields in engineering science.* *D. The presence in a university of fundamental scientists contributes to the innovative thinking process essential to the achievement of large technology jumps.*

APPENDIX C-4

EXAMPLE OF HAND-HELD RATIONALE SHEET

RATIONALE
FOR
CONDUCTING GOVERNMENT SUPPORTED AERONAUTICAL WORK

Rank Order	WORK CATEGORY: *TECHNOLOGY ADVANCEMENT*	BY SEGMENT: *UNIVS*				
	REASONS FOR GOVERNMENT SUPPORT OF WORK BY THIS SEGMENT	Man.Co.	Serv.Co.	Non-Prof.	Univ's	Gov.Labs
	A. *The training of students for the later practice of engineering is furthered by university activity in technology advancement.*	●	●		+	
	B. *Experience has shown in some cases, that the Government can obtain outstanding technology advancement from universities.*				+	
	C. *The effort in universities to achieve large jumps in technology can serendipitously stimulate the development of fundamental fields in engineering science.*				+	●
	D. *The presence in a university of fundamental scientists contributes to the innovative thinking process essential to the achievement of large technology jumps.*		+			●

\+ Reason Entered by this group (at least 3 members)
● Reason deleted by this group (at least 4 members)

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX C-5

RANKING METHODS AND COMPUTATIONS

INDIVIDUAL RANKINGS

The aeronautical leaders ranked many factors in the survey questionnaire and during the workshop. For instance, in the questionnaire, the participants ranked various types of organizations on the relative quality of R&D they tend to perform. Another important example was at the conclusion of the workshop when the participants ranked the basic rationale for government use of particular sectors of the aeronautical R&D community for conducting given categories of work. In all cases, the number 1 was used to indicate the highest rank in terms of merit and a larger number indicated a lower degree of merit. The numerical rankings extended from 1 to 5 or 6. The participants were not to skip numbers or use tied numerical rankings.

The ranking procedures for the survey questionnaire were the same as those for the workshop, with only two exceptions. The participants could use two additional types of rankings during the workshop. After ranking five statements of rationale from 1 to 5, they could then use blanks to indicate that rationale statements were valid, but of less significance than the numerically ranked items. They could also use a blackball (●) to indicate that statements of rationale were incorrect or invalid.

There were occasional ties, omissions, and other errors in the rankings submitted by the participants. Ties were incorrectly awarded for 0.8 percent of the total number of survey questionnaire ranks returned by all participants and in less than 0.1 percent of the total individual workshop ranks. Ranks were inappropriately left blank in 5.7 percent of the total number of rankings returned with the survey questionnaires. The ties and omissions could have reflected the participants' inability to differentiate among rankings for certain variables, a failure to understand the instructions, or simply a lack of interest. Ties and omissions were corrected in cases where the intended relative rankings were obvious. The remainder of the errors and omissions were taken into account in the scoring procedures. This procedure essentially treated ties and omissions as if the participants could not distinguish among the relative rankings of the associated variables.

SCORING INDIVIDUAL RANKINGS

Individual rankings were scored in a manner intended to provide complete and consistent sets of rankings for determining the statistical significance of the individual rankings and to formulate group consensus rankings. The scoring was done as follows:

Step 1. Whenever it was possible, errors were corrected to reflect the exact ranking order intended by the participant.

Step 2. Next, ties were given scores equal to the average of the ranks they would have had if they had been ranked in order, beginning after the next lowest discrete numerical rank.

Step 3. The scores of the other discrete numerical rankings were then adjusted upward or downward as would have been necessary if the ties had been ranked.

Step 4. Blanks were then given the next greatest scores. The blanks were scored as the average of the ranks they would have had if they had been ranked in order beginning with the next highest rank possible after all the ties had been ranked in order.

Step 5. Blackballs (●) were scored last. They received the highest numerical score possible for a given ranking by an individual. Blackballs were set equal to the average of the numerical ranks they would have had if they had been ranked in order up to the greatest possible value for that ranking.

The three examples on the following page illustrate this scoring procedure.

Example 1:

SCORING STEPS	A	B	C	D	E
Participant's ranking	2	5	4	3	5
1. Corrections	1	5	3	2	5
2. Scoring ties	1	4.5	3	2	4.5

(VARIABLES: A–E)

Example 2:

SCORING STEPS	A	B	C	D	E	F
Participant's ranking	2	3	3	4	5	4
1. Corrections	1	3	3	4	5	4
2. Scoring ties	1	2.5	2.5	4.5	5	4.5
3. Adjusting scores	1	2.5	2.5	4.5	6	4.5

Example 3 (Workshop only):

SCORING STEPS	A	B	C	D	E	F	G	H	I
Participant's ranking	2	5	1		3	●		3	●
1. Corrections	2	4	1		3	●		3	●
2. Scoring ties	2	4	1		3.5	●		3.5	●
3. Adjusting scores	2	5	1		3.5	●		3.5	●
4. Scoring blanks	2	5	1	6.5	3.5	●	6.5	3.5	●
5. Scoring blackballs	2	5	1	6.5	3.5	8.5	6.5	3.5	8.5

GROUP CONSENSUS RANKING

A group consensus ranking is a measure of the opinion of a group, as a whole, in regard to the correct ranking of items that are ranked in order by the individual members of the group. The group consensus ranking is the best estimate of group opinion when the relative rankings by members of a group are statistically significant (71:100 to 102). In the current study, this is taken as a level of probability of 95 percent or higher that the differences in rankings among all the items were not due to chance.

The group consensus ranking is operationally defined by the following measurements and procedures for calculating them:

Step 1. The scores discussed in the previous section were truncated to reduce distortions caused by high values assigned to blanks and blackballs. This often occurred when the number of judges was smaller than the number of items being ranked. Blanks were limited to a maximum value of 6 and blackballs were assigned a maximum value of 7.

Step 2. Then a group's scores for any one item were averaged. This was done individually for each item that was being ranked by the group.

Step 3. If four-fifths of a group awarded any item a black-ball then that item received a final group-consensus rank of • (meaning invalid or incorrect).

Step 4. The other items being ranked were then awarded positive integer ranks in the same numerical order as the average scores. This began with the number 1 and continued progressively toward higher numbers.

Step 5. Equal tied ranks were awarded in cases where the averages fell within a specific maximum interval of each other. This interval was taken as 0.25 based on a qualitative comparison of the data. The lowest average score involved established the base of this interval.

Step 6. Ties were given the minimum numerical value they would have had if they had been ranked in order.

Step 7. The remaining rankings were then adjusted to the values they would have had if the ties had all been ranked in order. This process skips the other intermediate ranks which would have been spanned by the ties.

The following example illustrates the process for calculating group consensus rankings for the workshop results.

Example for a Single Judge

	ITEMS								
	A	B	C	D	E	F	G	H	I
Score	2	5	1	6.5	3.5	8.5	6.5	3.5	8.5
Truncating	2	5	1	6	3.5	7	6	3.5	7

Example for a Group of Judges

	ITEMS								
	A	B	C	D	E	F	G	H	I
#1	2	5	1	6	3.5	7	6	3.5	7
#2	7	6	2	5	3	7	7	4	1
#3	1	5	2	6	4	7	7	3	6
#4	1	4	2	5	3	6	7	6	6
#5	2	6	1	5	3.5	6	7	3.5	7
Averaging	2.6	5.2	1.6	5.4	3.4	6.5	●	4	5.4
Rankings	2	5	1	5	3	7	●	4	5
Adjusting for Ties	2	5	1	5	3	8	●	4	5

APPENDIX C-6

EVALUATION AND ASSESSMENT FORMS

RELATIVE EMPHASIS IN NASA/NACA CENTERS

	Recommended Distribution of NASA's work
Basic Research	
Applied Research	
Technology	
Development	
TOTAL	100%

DISTRIBUTION OF WORK IN EACH AREA
(Percent %)

	Basic Research	Applied Research	Technology Advancement	Product Development	(Sample)
Man.Co's					10
Serv.Co's					25
Non-Prof's					15
Univ's					40
Gov.Lab's					10
TOTAL	100%	100%	100%	100%	100%

INDIVIDUAL ASSESSMENTS

DO NOT INDICATE YOUR NAME

Check below the type of organization that best describes the principal nature of your company, division, institution or government organization.

(Check one)

- ☐ Manufacturing Company
- ☐ Service R & D Company
- ☐ Non-Profit R & D Inst.
- ☐ Government Lab
- ☐ Government R & D Fund. Org.
- ☐ Other ______________ (Write in)

Check below the kind of aeronautical work that you are primarily concerned about in your current position.

- ☐ Basic Research
- ☐ Applied Research
- ☐ Technology Advancement
- ☐ Product Development
- ☐ Other ______________ (Write in)

APPENDIX C-7

PARTICIPANTS' REACTION TO TRIBUTARY TECHNIQUE

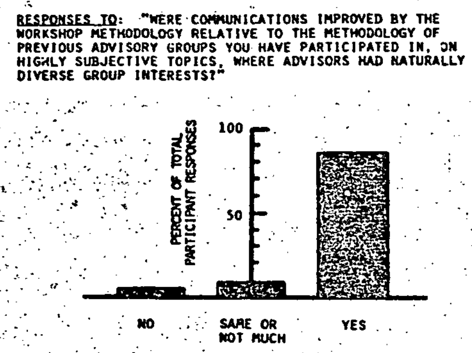

FIGURE 16: CRITIQUE OF TRIBUTARY TECHNIQUE AS COMMUNICATION MECHANISM

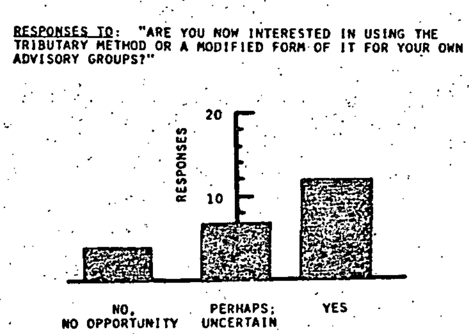

FIGURE 17: FURTHER USE OF TRIBUTARY TECHNIQUE

RESPONSES TO: "DO YOU THINK THAT BETTER RESULTS WOULD HAVE BEEN OBTAINED WITH MORE TIME ALLOWED?"

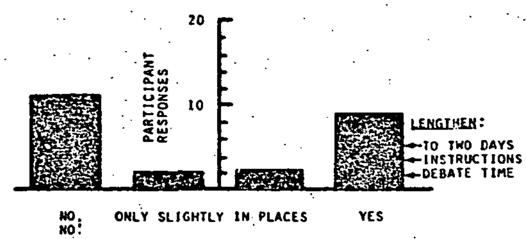

FIGURE 18: CRITIQUE OF TIME FACTOR

RESPONSES TO: "WHAT IS YOUR OPINION AT THIS POINT OF THE POTENTIAL VALUE OF THE RESULTS OF THE WORKSHOP YOU HAVE JUST COMPLETED?"

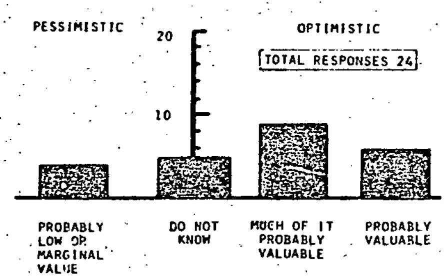

FIGURE 19: EXTENT OF OPTIMISM ON USAGE OF RESULTS; END OF WORKSHOP